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JOSEPH G. HORNER

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A PRACTICAL TREATISE

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AUTHOR OF
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ETC.

(SECOND EDITION)

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PREFACE

THE literature which deals with the subject of Brass moulding and founding is scanty, and not of recent date. This book is offered as an attempt to deal with the leading principles and practice of an interesting trade with which the author has been closely associated. The substance of these chapters has already appeared in the *Mechanical World,* but new matter relating to furnaces has been added.

Although not a comprehensive treatise on the subject, it is one which is reasonably complete. It should be of service to apprentices and students, as well as to the pattern maker and moulder, for whom chapters are written, since the two trades cannot be disassociated. Considerable space is given to descriptions of the furnaces, in which many improvements, and economies in working, have been effected during recent years.

JOSEPH G. HORNER.

BATH,
April 1918.

PREFACE

TO THE SECOND EDITION

A new edition of this work having been called for, I have taken the opportunity to add a chapter on Electric Furnaces. Some of these have been developed past the experimental stages, and have a promising future.

JOSEPH G. HORNER.

BATH,
Nov., 1920.

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BRASSFOUNDING

CHAPTER I

INTRODUCTION: ORIGIN OF BRASS

Brass.—The term "brass," as used in foundries, includes scores of different products, ranging from the hardest gun-metals or bronzes employed in the best machinery, to the soft yellow metal employed for cheap commercial goods. It is all "brass," notwithstanding that the range of physical characteristics is as wide as that between all the grades of iron and steel. "Brass" includes highly ductile metal, which can be hammered, bent, and rolled; and brittle metal, which will scarcely stand a blow. It melts at a lower temperature than copper, while it is harder, more lustrous, and more durable. It is used by engineers for the most durable bearings, many preferring hard bronze to steel for the bearings of lathe spindles, while it is tooled with the utmost ease. At ordinary temperatures machinery brass is very tough and the fracture finely granular, but when heated it is rotten and breaks to pieces under the hammer. Brass requires a furnace temperature of about 2000° F. to melt it.

Direct Mixing.—There are two ways in which the "metal" is obtained. One is by the direct admixture of copper and tin (gun metal), or copper, zinc, and a little tin and lead in many cases (brass); the other by the mixing of old metal of all conceivable qualities and grades, with or without a certain amount of new copper or tin. The first is followed when a very special mixture is wanted for a given purpose or to conform to strict specification; the second is that which is generally adopted in the large majority of work, because it is cheaper to buy old metal than new copper or tin, and easier to mix old metal than new brass. Large quantities of new copper can, however, be obtained cheaply from the

coppersmiths, consisting of shreds and cuttings of the best quality, bought for about half the price per pound of the original sheet. Every brass foundry has its large proportion of sprues, fins, some wasters, old castings bought or taken in exchange and allowed for, besides the scrap from the dealers, and these must be sorted out and used, and therefore often only a rather small proportion of entirely new ingot metal is mixed in a shop. On the successful mixing of metal much of the economical success of a foundry depends. The work generally devolves upon a man or men distinct from the moulders, and the knowledge gained is wholly that of experience—continued observation alone and long practice being the school in which success is gained. There are certain broad rules which are followed, it is true, but experience is still as necessary as in the mixing of cast iron. When metal is mixed for the first time, it is ingoted, and then remelted for casting. Ingot moulds are of cast iron, and each mould receives two ingots nearly divided across the centre, and the initials or name of the firm is in the bottom of the mould. Metal of any given quality is thus prepared and kept for use.

The difficulty of mixing metal is greater than that which the ironfounder experiences in making up a desired grade from scrap and pig. The reason lies in the fact that there is a far greater diversity in the melting-points and in the specific gravities of the various constituents in the first case than in the second. In fact, in the latter there is, for all practical purposes, no difference. But copper, tin, zinc, and lead differ so widely in these characteristics that it is impossible to put them all into the pot at one time, as can be done with various grades of iron in a cupola. If this were attempted, a good deal of separation would go on in the pot, and a large proportion of metal would go up the chimney. The fluxes used for brass to prevent rapid oxidation are charcoal powder, and broken glass. Borax is sometimes employed for the same purpose. Borax, coarsely pulverised, is used by the brass-founders of India, who cover the contents of the crucible with this. If they cannot obtain borax they use a rather larger quantity of common table salt.

In making brass from copper and spelter, the copper is melted first, and the spelter added. Some mixers adopt the plan of heating the copper before placing it in the crucibles. When it is

melted, the spelter, broken into small pieces, is added gradually. The mixture is then stirred, skimmed, and poured.

Old Metal.—It is easier, as well as more convenient, to melt up a certain proportion of old brass than to use all new metal. The brass is melted, and the proportion of copper required for the new metal, and then the zinc is added while the metal is in a viscous condition, or sufficiently fluid to permit of the movement of the stirrer. When the zinc is added, it must be warmed to drive off any moisture, and be introduced slowly in order not to chill the copper. After the whole of the zinc has been added, the cover is put on and the pot left in the fire from ten to fifteen minutes to get the metal hot enough for pouring. All the zinc put in will not remain in the alloy, because of some waste by volatilisation, notwithstanding every care. It is necessary, therefore, to put in an excess of zinc. Every remelting will diminish the proportion of zinc. The crucible must be removed from the fire as soon as the fumes of zinc begin to come off.

The Original Method.—The method of making brass by the direct admixture of copper and spelter has been termed the Birmingham method. It is more recent than the old process of cementation, the year 1780 being the date of its introduction. In 1781 James Emerson took out his patent for "making brass with copper and spelter." The brass industry was already one of very respectable antiquity and proportions, as is evidenced by the monumental brasses which occur in the old churches and abbeys. In fact, Henry VIII. passed an Act of Parliament prohibiting under severe penalties the exportation of brass; and Elizabeth granted the exclusive right of making brass to Humphrey and Schutz. In the year 1721 it was estimated that the brass industry gave employment to about 30,000 persons. In the specifications of brass making at this early period, calamine always figures. This is an ore of zinc, $ZnCo_3$. "Copper, calamy, and charcoal" occur in one under date 1728. In 1758 the mineral, blende, called "black jack," or "mock jack," or "brazill," or "red stone," was proposed as a substitute. Black jack occurs again in a patent of 1767, instead of calamy, or lapis calaminaris. This patent includes the manufacturing of brass into brass wire "by stone, or pit coal, instead of wood, now used." Copper also for making brass was refined "with wrought iron intermixed or thrown into

it." This extracts the "pernicious arsenical" qualities of the copper. And again, 1779, "mix $\frac{4}{10}$ granulated copper with $\frac{6}{10}$ of lapis calaminaris, or prepared black jack, and with a proper quantity of charcoal; put the mixture in large closed clay pots in a furnace, and melt with the necessary heat."

At last, in 1781, came the patent of Emerson for making brass with copper and spelter chiefly. Calamine was still included, but the inventor explains that his chief reason for using a small quantity of this was "more for confining the spelter by its weight than for the sake of any increase arising from it, and I have frequently omitted the calamine in the process."

A quotation from this specification may be of interest:

"I take spelter in ingots, and melt them down in an iron boiler; I then run the melted spelter through a ladle with holes in it, fixed over a tub of cold water, by which means the spelter is granulated or sholed, and is then fit for making brass on my plan. I then mix about 54lb. of copper shot, about 10lb. of calcined calamine ground fine, and about one bushel of ground charcoal together; I then put into a casting pot a handful of the mixture, and upon it I put 3lb. of the sholed spelter; I then fill up the pot with the said mixture of copper shot, calcined calamine, and ground charcoal. In the same manner I fill eight other pots, so that 54lb. of copper shot, 27lb. of sholed spelter, about 10lb. of calcined calamine, and about one bushel of ground charcoal, make a charge for one furnace containing nine pots, for making brass on my plan. The pots being so filled are respectively put into the furnace, and about twelve hours completes the process, and from this charge I have on the average 82lb. of pure, fine brass, fit for making ingots, or casting for making brass battery ware, or brass latten; and my brass, made as aforesaid, is of a superior quality to any brass made from copper and calamine."

This seems to have been not only the first, but the last patent relating to the subject. It covered the whole ground, and superseded the original time-honoured process. Subsequent patents relating to brass deal with its numerous alloys, not with any modification in the method of manufacture. Though of no commercial value now, it will be interesting to glance at this older method of making brass, followed previous to 1780. The process

was essentially that of cementation, the copper being brought into contact with the ore of zinc and maintained at a high temperature for several hours. Calamine was the ore generally used, hence the term "calamine brass"; but blende was also sometimes employed. The operation was performed in crucibles, several of which were arranged in a large furnace. The furnaces were either of the cupola form, or resembled it rather closely. In the general type of furnace, the melting chamber measured about 3ft. 6in., both in diameter and in height; was of a domed form, and built of firebrick; the bottom was formed of a circular cast iron plate. A large hole in the centre plate permitted of withdrawal of ashes, and several small holes flanking it admitted draught from the ashpit, communication with which was through a vaulted chamber. Cast iron nozzles, about 6in. high, were set over the draught holes, and firebrick set in fireclay built on the plate around the nozzles and level with them. The furnace was built within a mass of brickwork and surmounted with a brick chamber, through which rose a high cone. A hole in the top of the cupola served the purpose of a chimney.

The charges used comprised calamine, or blende, calcined and ground fine, mixed with pulverised coal, in the proportion of five parts of the former to two parts of the latter; the whole mixed and sifted through a sieve having a mesh of eight holes to the linear inch. Being then spread evenly over a level surface, several gallons of water were poured over it, allowed to stand, and again mixed and sifted through a sieve of four holes to the inch, and then mixed with 60lb. of best selected bean shot copper for best brass, a lower percentage of copper being used when inferior brass was required. The melting pots, of clay, were filled lightly with the mixture and set on the floor of the furnace, a large pot being placed in the centre, and smaller ones flanking it, the whole being covered with small fragments of coal resting on large lumps of coal made to bridge the tops of the pots. The furnace was closed and the coal left to burn into coke, after which the latter was pushed among the pots. Gradually the temperature was raised by operating a damper or cover in the top hole, and the cementation was effected in from ten to eleven hours. The copper was not allowed to melt during this time, because it would then collect at the bottom of the crucibles and would not be properly exposed

to the action of the calamine or blende. The brass which collected in the small pots was finally poured into the large, or ring pot, well stirred, and poured.

This process did not die out at once, some manufacturers preferring the old method to the new, believing a better product was obtainable thereby.

The Bronzes.—The bronzes are the oldest alloys; the brasses came later. But always in all specimens from all ages the analysis of castings has shown wide variations in composition. This may be accounted for by the crudeness of old methods of melting and mixing, and also probably by the volatilisation of tin and of zinc in repeated remeltings. The principal difference between the archaic bronzes and the historic brasses is the absence of lead from the first, and its presence in moderate quantities in the second. Traces of lead, it is true, occur in some of the old bronzes, which may be explained by its presence in the copper ores. Also; no zinc occurs in the ancient bronzes, but in the brasses of the historic period it is present in large but variable quantities.

The mixing of the bronzes does not appear to have advanced very greatly since the prehistoric and early historic periods. The copper-tin and copper-lead alloys are ancient. The methods of mixing the alloying elements now are similar to those which have been employed by brassfounders since the mixtures have been made directly of the separate metals. The knowledge which is new is that acquired by the studies of the metallurgists on the phenomena of freezing-out, aided by microscopical examination of polished and etched specimens. These have explained many things which were not understood previously. But they cannot be said to have materially changed practice. The melter may work more intelligently, but he nevertheless pursues the old methods in order to produce the same results. Oxidation must be prevented, the metals which fuse at a low temperature and which volatilise readily must be introduced with the same precautions, and so on. The changes which have come about have been those consequent on the introduction of some elements new to the trade—phosphorus, boron, manganese, iron, magnesium, aluminium. Many changes are made with these, but they introduce new difficulties of their own. Three products have proved successful—phosphor bronze, manganese brass, and aluminium bronze.

Early Bronzes.—Accepting the estimates of archæologists, we may believe that the art of bronze mixing and casting flourished 3000 years B.C. Neolithic remains contain ample treasures of the founder's art and craft. Bronzes survive from ancient Egypt, Nineveh, and Greece. In Roman times lead and zinc had entered into the composition of the brasses. Many of the actual moulds as well as the castings survive from prehistoric times. They are of burnt clay, sand, stone, and bronze, and are both open and jointed. Probably sand moulds were used, but if so they have perished. Only the permanent moulds for repetitive work have survived. Castings with lapping edges testify to the inaccurate jointing of moulds, for divided moulds were dowelled. Channels for ingates, and others for air vents, are present in some moulds. Hollow castings testify to the practice of coring. Castings have been found with cores *in situ*, and bad coring is observable in unequal thicknesses of metal. Even the practice of pouring a number of articles from a central ingate is in evidence. The crucibles of clay in which the metal was melted have survived the flight of time, and ingots of pure copper, besides runner heads, and scrap.

During those long periods everything was cast, even long sword blades, knives, sickles, daggers. The necessary hardness was imparted to the cutting edges by hammering. True gun metal was composed of nine parts of copper and one of tin.

Copper.—Comparatively little casting of pure copper is done. But it is wanted sometimes when the metal is too thick to be dealt with in tubes or sheets. The difficulty is to get it free from blowholes caused by oxidation and the occlusion of gases in the metal. The remedy is to add a deoxidiser which, while removing the oxide, will not remain in the metal to its injury. The materials used are silicon, manganese, magnesium, aluminium, phosphorus, zinc, and boron. The methods in which these are employed differ, some being in the elementary form, others in union, as silicon with copper, and boron with a flux. The methods of adding the deoxidisers vary also with each variety.

Copper is the base of all the bronzes and brasses, the predominant element which occurs in larger quantities than any of the others. Its primary function is to impart strength and toughness, and incidentally where these qualities are not in special

demand, as in ornamental castings, to vary the shades of red and yellow. The addition of the alloying elements in various proportions induces physical conditions of entirely new kinds—strength, toughness, hardness, ductility, specific gravity. Always they lower the melting points below that of copper, which melts at about 1982° F. Thence the alloys go in a descending grade of melting points down to 1645° F. for yellow brass. The melting point of tin alone is 449° F., of zinc 787° F., and of lead 621° F. The fact that these are so much lower than that of copper explains the difficulty of mixing the metals to form homogeneous bronzes and brasses.

The true gun metals contain only copper and tin, the proportions being 88 or 89 of copper and 9 or 10 of tin. From 1 to 2% of zinc is usually added, but only for the purpose of rendering the alloy more fluid and the castings free from blowholes. The standard gun metal of 88 copper, 10 tin, and 2 zinc gives the highest tensile strength with good elongation.

The stronger bronzes are made by the addition of phosphorus to the copper-tin alloy. The utility of the phosphorus is not as an alloying element in the same sense that tin is, but its value lies in its deoxidising property. It cleanses from the oxides of copper and tin, rendering the product sounder, more homogeneous, and more fluid, consequently the phosphorus content is very low and in some cases may not exceed a mere trace. These are the hard phosphor bronzes which contain little or no lead, but copper and tin almost or quite exclusively. A good phosphor bronze contains 89·5% of copper, 10 of tin, and 0·5 of phosphorus, the latter being introduced into the melt in the form of 15% phosphor copper. Phosphorus is best when added in the form of phosphor tin or phosphor copper to the crucible. The alloy should contain from 10 to 15 % of phosphorus.

Influence of Lead.—What is termed leaded gun metal is an alloy of copper and tin in the usual proportions, with from 3 to 8% of lead. This is added to some bearing alloys to serve as a lubricant. The globules of tin being imperfectly alloyed, fulfil that function. But the effect is weakening. The globules of lead sever the copper-tin crystalline alloy, and weaken the crystals. Lead is only of use either from the point of view of the machinist, because it tools easily, or in some bearing metals because it

lubricates an otherwise hard bearing. It does not form an alloy with gun metal, but separates in globules distributed through the mass. Where high tensile strength and good elongation are required, lead is inadmissible except in minute quantities. Any more than about 2% manifests its weakening effects. Hence the Admiralty specification for gun metal stipulates that lead, if present, must not exceed $\frac{1}{2}$%. Beyond about 3 or 4% it is liable to cause trouble, the risk increasing with the mass of the casting, and by pouring too hot. Thin castings pour best, because the lead has less time in which to separate out.

Influence of Tin.—In the copper-tin alloys the effect of making increases in the proportion of tin is to lower the freezing point of the alloy. Also, while pure copper and pure tin have each but one freezing point, due to the evolution of latent heat, the alloys have two, three, and four freezing points, the number depending on proportions—that is, they solidify in as many distinct stages, particular groupings of tin and copper which remain liquid for a while and become solid at the various freezing points. The theory of annealing bronze is explained by these facts. The bronzes which have a fusible constituent, freezing at a point much below that at which the main portion of the alloy solidifies, can be annealed by heating them to a red heat, and chilling. The explanation is that the more fusible alloy is melted, and made to solidify quickly, causing fineness of grain.

The separation of these constituents has a vital influence on the ultimate product. The larger the eutectic the more open is the structure, with resulting weakness and perviousness to water under the hydraulic test. Arsenic, though a deoxidiser, is believed to favour the separation of large quantities of eutectic, and it is therefore objectionable when present in larger quantities than $\frac{1}{4}$%. Pure metals with high melting points are stronger than those with low melting points. It is argued that metals with high melting points must be coherent and tenacious, because much heat is required to drive their molecules apart and reduce them to the fluid condition. As a corollary much force is required to overcome the cohesion of the molecules. As the metals with low melting points require but a slight elevation of temperature to render them fluid, the inference is that little force is required to separate the molecules. The two would seem to be connected.

It seems, therefore, to be a corollary that there is an intimate connection between the melting points of alloys and their strength.

The Brasses.—The brasses are composed of copper and zinc alloys. Copper-zinc alloys have been termed calamine brasses, because they were originally made from calamine or zinc ores. In these alloys the copper may range as high as 85 and as low as 60%, the zinc from 15 to 40%. Copper and zinc only may be employed, but usually tin and lead are included because the lead, acting as a lubricant, facilitates tooling operations. In the cheap brasses, lead and zinc occur in excessive proportions. The standard mixture for brass is 60 copper and 40 zinc, which gives the best tensile strength, and good elongation. Increase of copper and reduction of zinc increases the elongation, which explains the proportion of 70 copper and 30 zinc used for brass sheet. The red colour of a copper alloy changes to the yellow colour of brass when the copper falls below about 85%.

The brasses have been made the subject of investigation by M. Charpy. He proved that by varying the proportions of zinc between 30 and 43% a series of brasses may be prepared which possess such diverse properties that different members of the series represent almost distinct metals. The most malleable of the series has a tensile strength of 17·45 tons per sq. in., and elongates about 60%, while one with 40% of zinc has a tensile strength of 23·8 tons, and an elongation of 40%.

It is impossible to make mixtures to exact specification unless the alloys themselves are analysed. Lead is often present in tin, sometimes to the extent of 2 or 3%. But the chief difficulty arises from the employment of old metal and turnings, which form an uncertain mixture, unless great care is taken to keep the turnings and scrap from the same class of castings distinct from those of other classes.

When very exact and strict specifications have to be adhered to, a slight departure from the correct proportions of some of the secondary elements suffices to vitiate results. The tensile strength, yield point, elongation, or the value of the alloy as a bearing metal, will be injuriously affected. It is not always the quantity, *per se*, but the interactions of the elements that are of most vital moment. Chemical compounds are formed—oxides, eutectics, or double eutectics; separations leaving interstices,

mechanical mixtures entangled among chemical compounds, parts harder and softer, which in various ways damage the alloy for the particular function which it is required to fulfil. Most of these results can be visually detected in properly prepared microscopic sections.

Scrap.—But scrap fills a large and necessary place in the brassfoundry. It is economical, and its employment is unavoidable even if it is not bought from outside. Wasters are inevitable; runner heads, risers and overflow metal accumulate; turnings and borings come in from the machine shop. The composition of these products of the firm are known, and they can be sorted according to their grades. But it is when scrap is bought from the merchants that difficulty arises, because its composition is not known. Yet a man accustomed to judge of metals can form an approximate opinion respecting grades, sufficient to enable him to separate them accurately enough for mixing which has not to be done to close specifications.

In dealing with the outside scrap, considerable quantities of foreign materials are frequently present. Large slide-valves have white metal plugs in the faces; castings have iron bolts, and studs. And in addition much dirt may be present, insulating materials, and foreign bodies of various kinds.

When such outside metal is bought it should be remelted and ingoted, and the composition estimated by analyses of drillings, and the aspects of fractures. Then it can be brought to standard requirements by the addition of other metals. Ingots occupy less storage space than crude scrap, and they are much more handy for weighing out and charging into the crucibles. As it is generally accepted as a fact that ingoting new metal renders it more homogeneous than pouring direct from a first mixture, so the employment of scrap which has been melted at least once or twice should produce more favourable results than the use of new mixtures. The one point to observe is to separate the different grades of scrap. Bins should be provided for all the various grades both in the foundry and in the machine shop, and careless intermixture should be strictly prohibited. The turnings from different grades of metal should be put into their proper bins. Iron turnings and filings must be separated with hand-magnets, or in a magnetting machine, since the presence of small quantities

of iron is detrimental. A good deal of scrap is pure metal. Copper pipes, sheets, wires, are excellent materials to mix new metals from. Brass condenser tubes are of known composition suitable for remelting as such, or with definite proportions of new metals to be ingoted and tested.

In melting scrap, oxidation is reduced by covering the surface with charcoal broken into small pieces. Without this precaution the oxides would form a crust on the surface, causing much loss of metal and altering the percentages of composition of the alloy. It also reduces the absorption of the sulphur from the fuel.

The use of a flux is to unite with the impurities in the scrap and form a slag. The higher the zinc content the larger the amount of flux required. Borax, glass, rock-salt, and salammoniac are common fluxes, but others are employed. Stirring the metal is a necessary process in order to ensure homogeneity. It is done in the crucible, and as often as a fresh alloying element is added. It lessens the risk of blowholes and other imperfections.

Bearing Metals.—At one period gun metal was the only material that was considered suitable for bearings. These were commonly termed "brasses," though they were not made of copper and zinc, but of copper and tin. These have passed mostly out of practice in favour of better bearing alloys, the earlier of which were known as babbitt, the term originally denoting one composition only. But the genuine article became discredited because of the rivalry of cheaper mixtures, just as gun metal and the true brasses have been imitated.

The object of the babbitt was to form a comparatively soft and self-lubricating lining to a more solid bearing. It supplied the plasticity necessary for the self-adjustment of the slight inequalities of the journal. Provided these inequalities were not present, a hard bearing would be the best possible. But the hard gun metal brasses often failed because they were lacking in the property of self-adjustment. When the bearings sank and got out of alignment, or shafts became bent, the bearings were scored, and cut up, and heated. The remedy lay in self-adjusting bearings. Phosphor bronze has excellent wearing qualities because of the presence of the hard phosphide of copper. But it is not plastic, and cannot accommodate itself to the uneven movements of long shaft journals, for which a white metal is better. If lead is added

to phosphor bronze the lead particles form soft spots in a hard matrix, which are favourable to lubrication.

The problem of bearing metals of the soft or white group is associated with the lavish employment of tin, antimony, and lead. Zinc is excluded from these, but tin is used as a hardener and strength-giving element. It assists also the incorporation of the lead. Its present high price demands economy in its employment. Phosphorus in small quantity is useful as a deoxidising element, but in excess it produces hardness. Just what quantity of lead to use has never been answered to the satisfaction of all concerned. The metal mixer and the moulder prefer a low lead content. The man who pays thinks these men too conservative of lead, and too extravagant with tin and copper. An old formula nevertheless is: Copper 79%, tin 10%, and lead 10%, to which 1% of phosphorus may be added as a deoxidiser. By using these proportions the tin forms an alloy with the lead, holding and fixing it in solution. But if the percentage of lead is materially increased, trouble arises in consequence of the separation and settling of the lead in the lower part of the mould. This is one evil. Another is its precipitation from the copper which goes on after the copper has cooled below its fusing point, and while the lead is still molten, and which continues until the fusing point of lead is reached. Finally, there is the oxide or ashes thrown off by the lead. As an extreme which is practicable, the following is recommended: Copper 73%, lead 18%, tin 6%, and ferro-manganese 3%. Anything over this results in heavy loss of lead and an unsound alloy.

The difficulties of melting an alloy containing a large element of lead in a state of mechanical mixture, which has a fusing point something like 800° F. below that of the copper, are insuperable. Even in adopting reasonable proportions, many precautions have to be observed to get decent results. The oxidation can be minimised by keeping the surface covered with charcoal, both when melting and pouring. When pouring, the surface need only be uncovered just at the spout, so keeping the air away from contact with the main surface. The metal must be stirred before pouring. The mould should be filled as quickly as possible. Bottom pouring with a good head is desirable. Good venting is essential.

It is probable that only a mechanical union of lead and copper

is made in any proportion of lead of over $4\frac{1}{2}\%$, beyond which the separation of the lead and copper is manifested. The difference in their specific gravities and fusing points then prevents a true union. The difficulty is how to minimise the evils incidental to the mixture. Sudden or rapid cooling enables the alloy to hold more lead in solution than when the alloy is poured with sand moulds. Hence, when white metals are poured as linings into metal bearings, as much as 60% of lead is possible. Professor Goodman ascertained that the presence of some very minute impurities in bearing metals increased the friction out of proportion to the quantity of the impurities. But the governing condition was the atomic volume of the impurity. Metals of small atomic volumes, as aluminium, had this effect. Metals with larger atomic volumes than the main body of the alloy, as bismuth, reduced the friction, provided a small quantity only was used.

Manganese Brass.—Manganese brass has a copper-zinc alloy as its basis, with small quantities of tin, manganese, lead, and iron; but the two last are not invariably present. Its tensile strength is higher than that of brass, its elongation less. Its principal value lies in its resistance to corrosion, which is the reason why it is used for propellers and marine service. The difficulty of successful casting lies in the obstacles set up by the differences in the melting points and specific gravities of the constituents. Manganese melts at 1245° C., zinc at 419° C., and tin at 232° C. The manganese is used in the form of cupro-manganese, or of ferro-manganese if iron is to be included. Or the iron is added in the form of tinplate clippings, because these melt readily and are free from oxide. Thorough mixing and rapid melting are necessary if volatilisation of the zinc and oxidation of the iron are to be prevented. The pouring of manganese brass, and bronze, has to be done quickly. The gates should be large, and the mould poured, when practicable, from the bottom. Skimming gates and risers are helpful. The metal must not be poured too hot, nor may it be overheated in the furnace without bad results following.

One of the chief difficulties of the melter is the mixing of alloys which have a wide range in melting points. Generally the less fusible metal is melted first, and the more easily fusible added. In adding zinc to copper the large amount of zinc would

set the copper if it were introduced in one lump. It is therefore added in smaller quantities, a piece at a time, and plunged below the surface of the copper, the pieces being warmed first. Another method which has been adopted is to melt the zinc first and introduce the copper in the form of thin cuttings into the zinc. But much of the zinc volatilises, notwithstanding that the surface is covered with charcoal. Another method is to employ a "temper"—that is, an alloy of the two or more metals to be added to the main quantity. This is a common practice, and there may be more than one temper mixture in a multi-alloy. The difficulties which result from the great differences in the melting points of the constituents are thus overcome, because the melting points of the secondary mixtures approximate.

Nickel Alloy.—German silver alloy is difficult to mix, the trouble arising from the nickel present, the composition being nickel-copper and zinc in varying proportions. The cause of the trouble lies in the very rapid chilling of the nickel, its thickening by rapid oxidation, and its enormous shrinkage. The latter is so great that the runner must sometimes contain as much metal as its casting. In no case should the runner have less area than the maximum area of the casting. The mould must be of an open sand and thoroughly vented. The methods of mixing vary widely. The most usual way is to melt the bulk of the three metals, nickel, copper, and zinc, together at once, then to add an alloy of one part of zinc and one-half part of copper by weight, followed by one-fifth by weight of the first charge of zinc, the whole being then heated and poured. Another is to prepare an alloy of copper and nickel covered with charcoal. This is remelted, and to it the required quantity of zinc is added in small pieces, warmed up first in order not to chill the molten metal. Another method is to melt granulated nickel, and add brass which contains the required amount of copper, adding more zinc if necessary. Yet another is to use Monel metal with the required quantity of nickel, and to add the necessary balance of copper and zinc. Also layers of copper, zinc, and nickel are placed in the pot, successive similar layers being superimposed until all the copper has been charged. One-third of the total nickel and zinc is retained until the contents of the pot are melted, and these are then added.

CHAPTER II

FURNACES, CRUCIBLES, SANDS

The Persistence of Original Designs.—Probably no class of furnace has undergone less change than that used during the last eighty or a hundred years for brass melting. With some modifications there is but one type used in most foundries to-day. It is that which is constructed almost wholly of brickwork, and which is sunk below the level of the floor. It is built into a pit in the floor, in order to permit of the melter standing above the furnace when charging or when lifting out the crucible. The height of the top of the furnace above floor level is usually from 8 to 12in. The pit is utilised as an ashpit, and all the draught required for combustion passes down into it from above through a grating. These are retained in hundreds of foundries.

Brass is melted easily; the amount of coke used is not large in proportion to the value of the metal. A single furnace suffices for a small cast; for continuous and heavy work the product of a battery of furnaces can be requisitioned. For the heaviest work only is a different type of furnace found more convenient, the reverberatory being then used in preference. For very small casts the portable furnaces are held in considerable favour. These may be either set upon the floor or sunk below it. There has not been, therefore, until very recently nearly so much variation in brass-melting practice as there is in that of iron melting.

The general limit to the dimensions of the older brass furnace is the quantity of metal which a man or two men can lift out. From 80lb. to 120lb. is not often exceeded, and the furnace for such pots is about 18in. to 20in. square. The smallest furnaces are about 9in. to 12in. square. Between these limits, therefore, most are built. They are arranged in rows in order to permit of the melting of a quantity of metal, divided between several crucibles. There are also the advantages that different qualities of metal can be melting

at one time in different furnaces, and that when repairs are necessary to one or two furnaces the melting can be going on in others.

Although a brass furnace is thus in its essential elements a very simple structure, the melting of brass easy, and the typical furnace fairly constant, yet there are more minor variations therefrom than some would expect to find. Only in recent years have any modifications worthy of note been effected in furnace construction. Several of these have been long enough on their trial to have established themselves in public favour. So that our illustrations will range from the simplest arrangements for brass melting to the later, including the blast designs.

It is very easy to melt brass. It may be melted in very small quantities in an ordinary kitchen grate, if all the air is made to pass through the fire itself. This is effected by closing the front bars with a piece of sheet iron, and closing similarly the opening above the grate to the chimney, so causing all the air to the chimney to pass up through the grate bars and through the fuel. In a large grate nothing more is needed; in a small one the bellows may be brought into request, a hole being made for the insertion of the nozzle near the bottom of the sheet in front of the grate.

Air Furnaces.—Brass-melting furnaces were at first always air furnaces—that is, there was no artificial blast, but only the natural draught of a tall chimney. The draught is soft and the arrangement convenient. Generally the draught furnaces are built permanently in the foundry, and are therefore connected with a stack. A good many furnaces are, however, used with blast, and these, when well constructed, give superior results. But blast is not necessary for melting brass in the ordinary furnaces. A moderate draught, such as can be obtained by a chimney of about 20ft. high, is sufficient. It is desirable to be able to regulate its intensity in order to get a good heat rapidly, and to check the melting when necessary for a season. A damper of the sliding type across the chimney, a little way above the furnace, is the commonest arrangement. Or it can be on top of the chimney. Or it can be placed in the ashpit in front of the opening leading to the grates. A brass-melting furnace can therefore be built anywhere where a chimney happens to be. It is only necessary to build it against the chimney and connect it thereto.

A Simple Furnace.—A small furnace for one crucible can be built entirely above ground in the manner shown in Figs. 1 and 2 (being a cross section and front view respectively), and at little cost. The sides are built of brick to a square form. The bricks may be arranged as headers, as shown, or if the furnace is of very small dimensions, sideways. If one thickness only is used, firebrick must be employed; if more than one, the inner layer only need be of firebrick, which must be cemented with fireclay.

The grate is most conveniently made of single square bars *b*, which will rest on the inside on a ledge formed of bricks placed end up. At the front they can rest upon a bar *a* built into the brickwork, the bars being sufficiently long to be grasped and pulled out for the purpose of dropping the fire. The top (A) is shown as

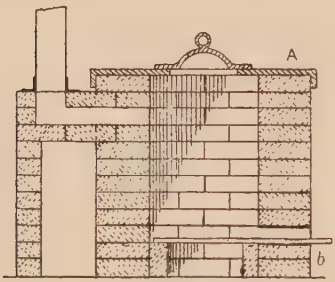


Fig. 1

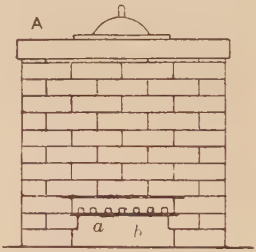


Fig. 2

a plate of cast iron with a ledge all round to embrace the brickwork, and having a hole for the crucible, and for firing through. The cast-iron top is often dispensed with, a consideration when a cheaply-made furnace is in request. In its place a wrought iron band can be shrunk round the top, and one or two others lower down would be advantageous. The flue opening will be left in the brickwork near the top by the omission of a single brick, or of two bricks, according to whether they are arranged sideways or endwise. The stack and its connection will depend on circumstances. The cheapest way is to get a long piece of sheet iron tube, as shown, riveted up. This becomes red hot during melting, but that is of no consequence out of doors. This can then be attached to the brickwork with a broad angle-iron flange, and

the top can be steadied with a light rod against a building adjacent. The weight can be taken by a wall, one brick thick, built under it, as in the figure.

Round Furnace.—Round furnaces have been long in use in Birmingham and elsewhere. One of these is shown in Fig. 3. This furnace is on a level with the floor, and is supported on columns of brickwork or of cast iron. The base is formed by a cast iron plate A, having a hole in the bottom across which the firebars are laid. The furnace shell B is of sheet iron rolled to the circular form and riveted. This is lined with bricks, and rests upon the cast iron plate. When the bricks become burned badly the circular casing is lifted bodily and relined. In this case the

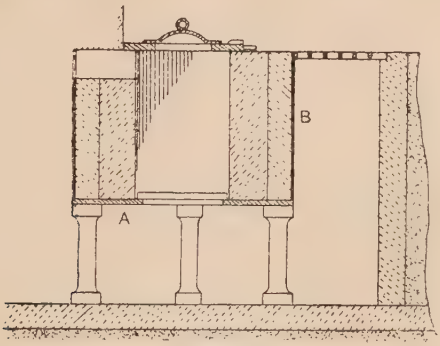


FIG. 3

furnace is level with the ground floor, but there is no large quantity of brickwork required, nothing except the actual furnace lining, which can be renewed and replaced with little trouble and expense. The distinction between the outer and the inner layers of bricks is indicated in the figure.

Early Gas Furnaces.—The endeavour to substitute the Bunsen flame for solid fuel and natural draught in small crucible furnaces has been made several times, in order to permit the utilisation of portable furnaces in places where it would be inconvenient to build or to utilise an existing chimney, and also to avoid the mess of cinders.

George Gore, of Birmingham, patented a gas furnace in 1863, in which the gaseous products, after heating the crucible, were made to pass round and down outside the furnace casing to the

chimney. One type of furnace, the largest, is illustrated in elevation and section in Figs. 4 and 5. A smaller one differed only in minor details.

The furnace itself, A, was a tube of fireclay enclosed in a cylinder of sheet iron B, lined with fireclay C, an annular space being left between A and C for the passage of the waste heat on its way to the chimney D, which was 5ft. or more high. The

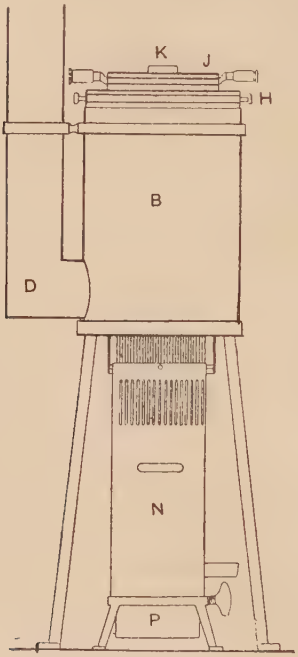


Fig. 4

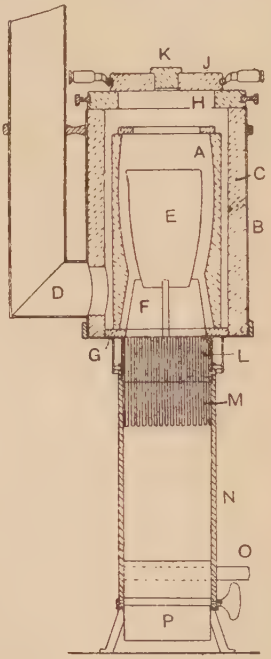


Fig. 5

crucible E rested on a fireblock F, by which it was kept in a central position, and which was supported on a fireclay disc G on the bottom of the furnace. A slab of fireclay H covered the furnace, and another cover J, with handles and with central plug K, permitted the crucible to be charged, and the melting observed.

The combustible gaseous mixture was produced in various ways, one only being illustrated in the figure, but one principle was common to all. Air and gas, in regulated proportions, were mixed in one section of the apparatus, and as they issued into the bottom

of the furnace, a certain portion of atmospheric air was admitted, and the whole ignited. In one case a fluted or corrugated copper cone was employed for the mixing of the charge, the gas and air rising within the cone, and the additional air outside. In the figure a series of parallel plates of fireclay L is employed, resting upon a series of parallel metallic plates M. The gas and air coming up through the tube N passed between the pairs of plates, while air entered from the outside through the openings seen in

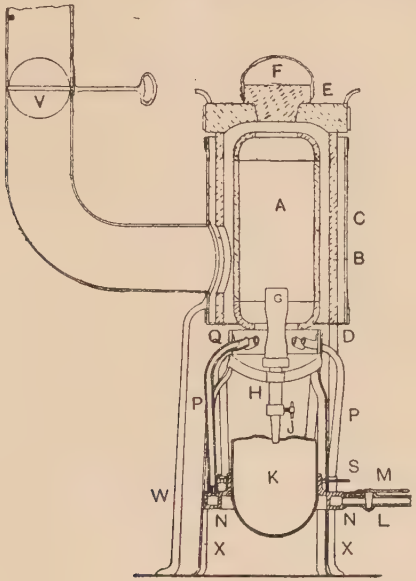


FIG. 6

Fig. 4, and passed between the plates of each pair, the mixture igniting at the top beneath the crucible. In the figures O is the gas pipe, and P the air valve.

Johnson's furnace, patented in 1868, was also an endeavour to use common gas and air with a small chimney draught for the melting of metal. It is illustrated in section in Fig. 6. It consists essentially of two portions, the furnace itself, and the appliances for introducing the gas and air.

In the figure, A is the melting furnace, or "muffle," arched at top and bottom to impart a reverberatory action to the heat. This is surrounded by a clay cylinder B, with an intervening

chamber, which is traversed by waste heat on its way to the chimney. This again is surrounded by a sheet iron casing C, the whole standing on an iron base D. The cylinder has a cover E, with a circular opening which is fitted with a plug F, through which the melting operations can be observed. Both E and F are removable by their handles. The crucible rests upon the clay cylinder G, and the height of this can be regulated by moving its stem in the cylinder H, in which it can be tightened by the screw J. K is a chamber which would catch any metal in case of accidental fracture of the crucible.

The provision for combustion of the air and gas by which the metal is melted is seen below the furnace. The gas enters through the tube L, and its supply is regulated by the plug and handle M, which is provided with a pointer for indicating the amount of gas which passes through. The latter enters an annular chamber N, provided with gas jets, each of which enters the lower end of a curved pipe P, which passes within the ring Q, immediately below the furnace. Nozzles cause the combustible mixture to converge below the entrance to the muffle furnace. The supply of air is regulated by means of holes in the pipes P, encircled by collars like a Bunsen tube, also with holes. These collars being made to move round the pipes, permit the holes to remain full open, or close them partially, so regulating the supply of air. The action of all the collars takes place simultaneously on moving the handle S. V is the chimney regulator, W are the furnace supports, X those for the ring Q.

In these examples, therefore, we have the application of gaseous combustion and its regulation, the utilisation of waste heat, the employment of a chamber to receive any waste metal, and the use of moulded fireclay, and of fireclay covers.

Removable Linings.—It is interesting to note how other old ideas recur from time to time in later practice. Two of the features which are associated with the present subject, and which occur in some modern furnaces both in England and America, are old. They are the fitting of removable refractory linings to furnaces, and leaving a space between the lining and the casing to serve as an air space or to be filled up with coke and dust, sand, lime, or other bad conductor of heat, or left open. These formed the subjects of a patent granted so long ago as 1861, thus:

"Within each chamber is then inserted a lining of brick, tile, or other form of fireproof clay or suitable compound, or by preference of ganister or other silicious stone, ground, moulded and burnt in the ordinary manner, and such lining may be either all in one piece or in several pieces, so as to suit the particular furnace in which it is intended to be used. The lining above described may be either used alone or between that lining and the permanent part of the furnace, in case the heat is of such degree as to make it desirable for the further protection of the permanent part of the furnace; a space is left between the brick, tile, or ganister lining above described and the permanent sides of the furnace, which space is filled up with coke dust, charcoal, sand, lime, or other bad conductor of heat. Thus, when the inner lining or linings become useless from being burnt away or by accident, and a new one is required, the old one is removed and the new one introduced, without disturbing the main brickwork or structure of the furnace."

Portable Furnaces.—Though these furnaces are termed portable, they are so only in the sense that they can be set down anywhere for service and removed elsewhere if required. This distinguishes them from the brick furnaces, which, once built, are fixtures, the position of which can only be changed by pulling down and rebuilding. An absolutely portable furnace is one in which the crucible and furnace can be carried to the work to be poured, the advantages to be derived from this arrangement being especially applicable to statue founding and other ornamental work, in which it is desirable to construct the moulds at some distance from the furnaces. In a patent taken out in 1877, on behalf of Alfred Pratt, the method of carrying out the idea of absolute portability is effected in the following way:

The furnace is of sheet iron, lined with fireclay or other suitable refractory material, and hinged on trunnions, and the fire is urged with blast. The metal is first melted in the crucible, after which the blast is shut off, and the light furnace with the contained crucible is carried bodily away to the mould with an encircling shank and cross handles, similar to those employed for common foundry ladles, to any distance for pouring. The metal is prevented from cooling during transit by the heat of the fuel surrounding it, by that of the refractory lining, and by the closing of

the mouth with a cover. The crucible cannot sink by the burning away of the fuel, because it rests upon a refractory block.

The Drop Bottom.—Since there is little that is new under the sun, it may be interesting to note an English patent of 1854, in which both the moulded lining and the drop bottom grate occurs. The lining was composed of a mixture of glass-grinder's sand and fireclay, preferably one part of the former to three of the latter being used. This was made into a plastic mass with water and poured into an annular space left between the brick casing and a

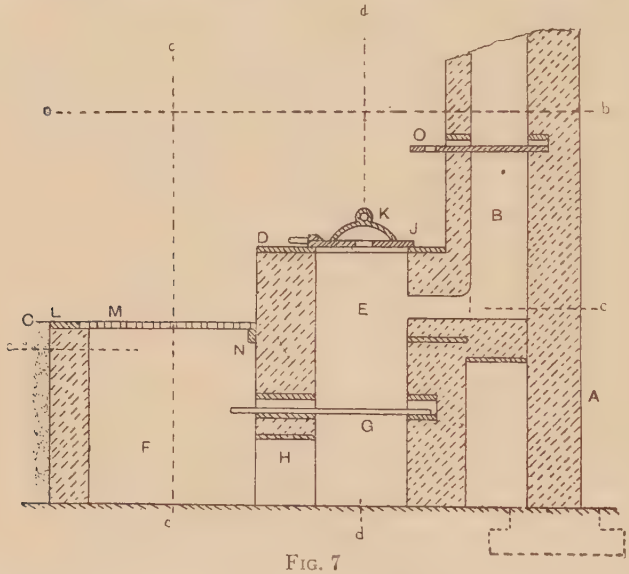


Fig. 7

circular wooden mould of the same size and shape as the interior of the furnace. The wooden mould was tapered and provided with a handle at the top to permit of its being withdrawn without disturbing the moulded mass. The complete drying was effected by heat. A moulding block was set in the chimney, opening at the same time as the block for the circular portion of the furnace. In this case, therefore, the moulded lining was made *in situ*.

The grate was provided with a lever by which it was raised and lowered. It was held up against the bottom of the furnace by a pin, which was knocked aside with a hammer when the grate had to be dropped.

Standard Air Furnace.—Figs 7 to 11 represent the standard English type of furnace used in brass foundries, in which the melting is effected by the natural draught of a tall chimney. It holds its place persistently, varying in little except in dimensions, which also range within narrow limits. It is not the best or most economical type, but then it has the merit of being readily constructed and repaired, and easily worked.

When several furnaces are required, as is necessary in the regular brass shops, they are simply a repetition of one—varying usually in the dimensions of the melting hole to take crucibles of different sizes, but not in external dimensions. Instead, too, of

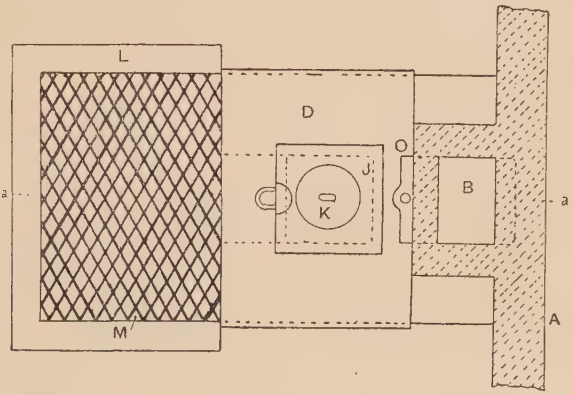


FIG. 8

making a separate chimney for each furnace, there is a flue common to each, running horizontally behind, and connecting them to a single chimney.

Furnaces of this type are always built against a foundry wall. This is indicated at A in the figures, the chimney B being shown built inside the wall. The level of the foundry floor is at C—C, and the top of the furnace at D. The height from C to D ranges from about 8in. to 12in. only, in order to permit of the melter while standing on the grating at the level C—C to be able to work the furnace and crucibles enclosed in E, from above.

Fig. 7 is a vertical section through the furnace E, chimney B, and ashpit F, taken in the plane *a—a* of the plan view Fig. 8, which last is taken in the plane *b—b* of Fig. 7. Fig. 9 is a sectional plan in the broken plane *c—c* in Fig. 7, taken through

the furnace, its connecting flue, and the ashpit below the grating. Figs. 10 and 11 are vertical sections, the first through the furnace E in the plane *d—d*, Fig. 7, and the second through the ashpit F in the plane *e—e* in Fig. 7.

These furnaces are built of common brick, with the exception of the linings which are exposed to the heat, and for which firebricks set in fireclay are used. The furnace E is also lined with fireclay as a protection to the bricks, which lining requires renewal at intervals of a few weeks, dependent on the amount of wear and tear of the furnace. Brickwork is carried over openings on cast iron plates which are built into it. The positions of these are indicated in the figures.

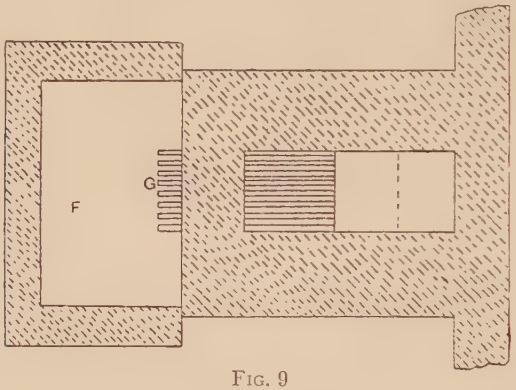


Fig. 9

The fuel is carried on the grate bars G, made of wrought iron, and laid in loosely. This seems a primitive method, but it is nearly universally practised. The ashpit F serves the double purpose of allowing down-draught to the furnace, and of affording access to the labourer who cleans the furnace or furnaces. The ashes drop down, on the drawing out of the bars G lengthwise, and are then raked through the arch H into F, whence they are shovelled up into a wheelbarrow on the floor above, or out through a culvert at one end.

The brickwork of the furnace is bonded together with a cast iron plate D, having end flanges. This will be about 1½in. thick, cast in open sand, and having a hole or holes cast out of the same size as the furnace openings. These plates invariably crack after a while, and are generally suffered to remain so until they open

badly. It would be worth while to adopt the method of casting expansion slots in order to lessen risk of cracking.

The opening is closed with the cover J, and tile K. Both are cast, or the cover is cast and the tile made of sheet metal. The cover J is about 2in. thick, and the metal in the tile may be $\frac{1}{2}$in. There is a small hole in J to permit the furnaceman to look into the furnace, and insert the poker without sliding the cover aside. It is easier to move K than J, and the man is better protected from the heat than he would be if J were moved aside. The latter is heavy, also, and is only moved for making the fire, inserting the crucible, and taking it out.

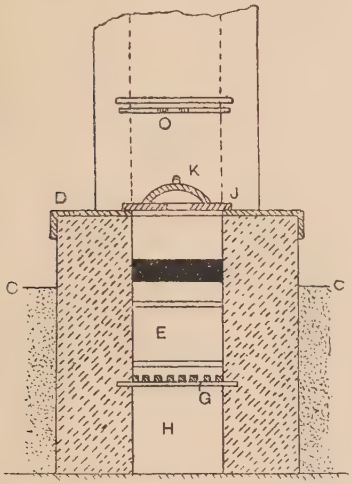


FIG. 10

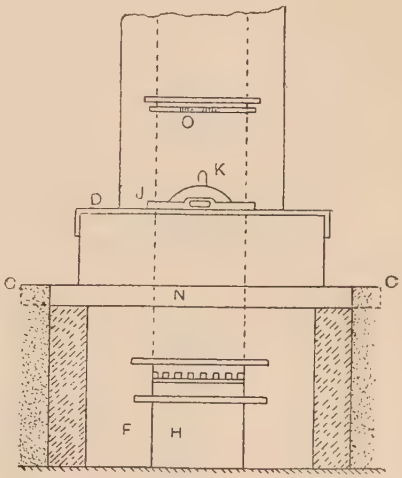


FIG. 11

The edge of the ashpit is protected with a cast iron framing L, bedded on the brickwork, and leaving a ledge into which the footplate M is fitted. The inner edge of the latter rests upon a bar N built edgewise into the brickwork. The footplate M is of the grating type. It is either cast with diamond-shaped openings, or other openings of suitable form. Or, it is made of separate loose square bars of wrought iron, let into recesses cast or cut in the framing. The first is rather clumsy when it has to be lifted; the second is preferable, provided the bars are fastened together in sets. Cast iron plates, too, are conveniently made in short lengths.

To regulate draught, the damper O is fitted. This is conveniently placed across the chimney within easy reach of the hand. It may, however, be fitted to the top of the chimney with a hinge, and be operated with a jack chain.

To melt the brass, the fire is built on the grate bars and allowed to burn up clear before the insertion of the crucible, which is generally warmed up on the cover. When the furnace has been heated equably, the fire is raked, the coke pushed down, the crucible inserted and charged, and fresh coke thrown in

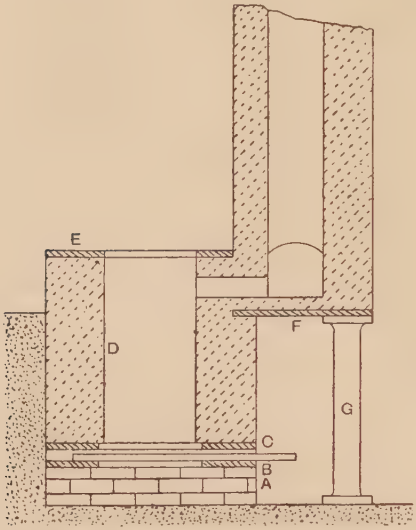


Fig. 12

around it. The lid being put on, coke is thrown over it, covering it and coming to the top of the furnace, which is then closed, the damper put well open, and the furnace allowed to rise to its highest temperature.

These figures are drawn to a correct scale, and may therefore be measured from for small and large furnaces. Roughly, a furnace 15in. or 16in. square in E would be 2ft. 5in. or 2ft. 6in. deep down to the bars. It would require a chimney 10in. to 11in. square, and 20ft. to 25ft. high.

In strictness, a brass-melting furnace should be built to an enlarged section in the area occupied by the belly of the crucible.

This is not done, because the bricks do not lend themselves to the arrangement, and because sufficient area can be obtained by having a furnace amply large enough for the crucibles it is intended to take; 5in. or 6in. is usually allowed on each side of the largest part of the crucible. If the space is much more contracted, there is not sufficient reserve of heat to melt the brass, but additional fuel has to be put in, which delays the melting.

Location of Furnaces.—In England the practice is almost universal of locating the brass furnace pit within the shop and covering it with a grating. The results are that the draught has to pass to the bottom of the furnaces from above, and in order to clear out the ashes it is necessary to remove the grating and

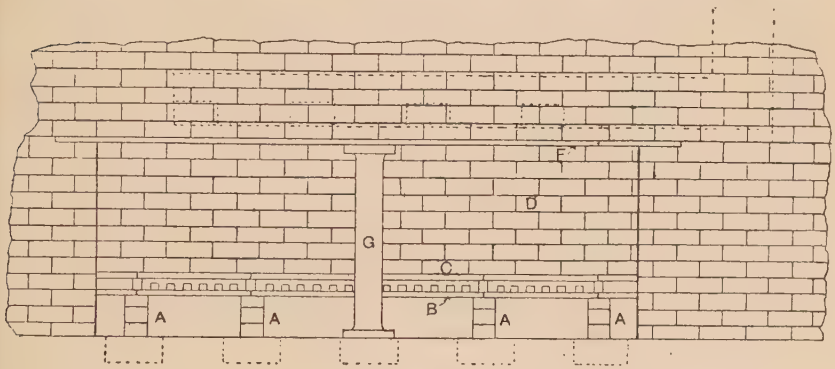


FIG. 13

throw out the ashes with a shovel. Or else they have to be taken out through an archway at one end. It is necessary to have the furnaces within the shop for convenience of getting at the metal. But the ashpit might often be placed outside with advantage. The furnaces are always next a wall, and there is no difficulty in carrying the ashpit under and outside the wall.

Figs. 12-15 illustrate an arrangement of furnaces with the ashpit outside the shop. They are built to come about 6in. or 8in. above the floor. The short flues lead into a horizontal flue or culvert running parallel with the furnaces, and leading into a stack at one end. Plates of iron are built in in certain parts to support brickwork. Fig. 12 is a vertical section through the furnace, Fig. 13 a rear view of the pit, and Fig. 14 a plan of the entire arrangement. Fig. 15 shows foundation plates for the furnace.

In these figures, low brick walls A are built in positions to come between each furnace, and of a suitable height. Upon these, cast plates B, Fig. 13, with square holes, are laid, then cast bars of a depth slightly greater than the depth of the grate bars, then the other square plates C, and upon the latter the brickwork D of the furnace is built. When the brickwork is completed, the top E is laid upon it. This may be in a single casting when two or three furnaces are concerned, but it must be

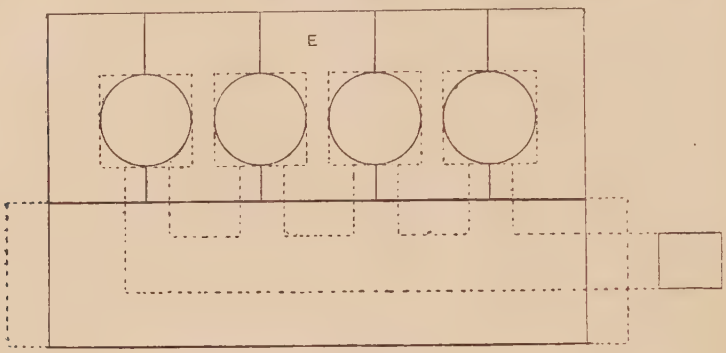


Fig. 14

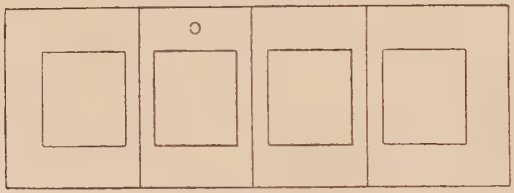


Fig. 15

in short lengths for a long row of furnaces, because a short length can easily be replaced, and is not so likely to disturb the brickwork by its expansion. The top castings are jointed either midway between, Fig. 15, or else through, the holes. Expansion slots may be cast round the holes, for the reasons previously mentioned.

The grate bars are pulled out at the outside of the shop, the wall of the latter being built next the furnaces. The flues are carried on cast iron plates F, which rest at the ends on masonry, and if the row of furnaces is of considerable length, they will be

supported on one or more intermediate places on columns G of cast iron, or on brickwork walls. The longitudinal flue or culvert is built on the iron plates, as are also the short furnace flues leading to it, and it leads into the stack at one end.

Figs. 16-18 illustrate another furnace. The pit within the shop is lined with brick in the usual way, and the floor cemented.

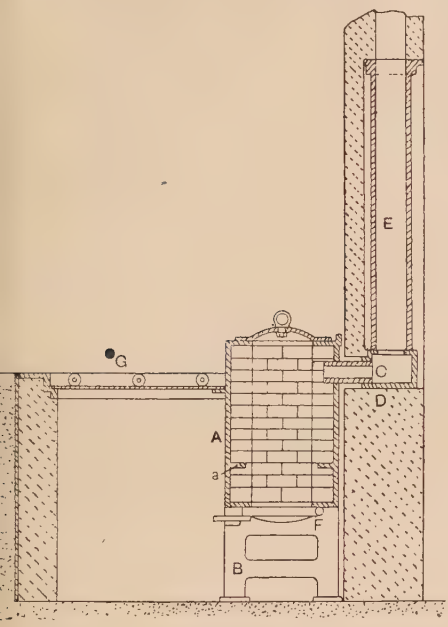


Fig. 16

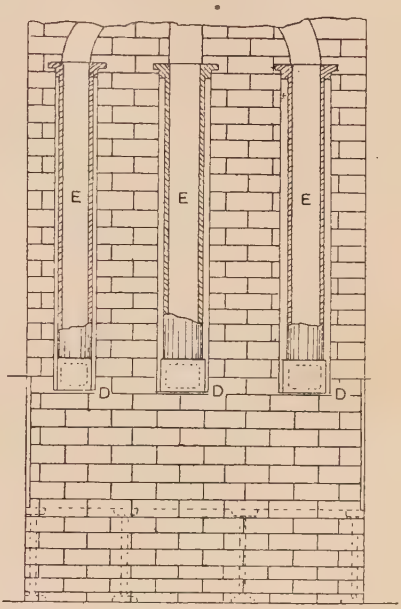


Fig. 17

It differs from other designs mainly in the furnace casings A being each of a single casting $\frac{1}{2}$in. thick, and in the stack being lined with cast iron pipes E, easily renewable. The details are as follows:

A, A are the casings, having flanges cast on top and bottom, within which the firebricks are enclosed. Small corner flanges are shown at *a*. These are cast in order to separate the lower bricks, which burn out most rapidly, from the upper ones, so that the former can be renewed without the necessity for relining the whole furnace. This practice is also adopted in other furnaces. The casings A, as many as are required in the row, are supported on standards or stools B, 18in. high, of cast iron, as shown. From

between these the ashes are raked out. In the back of each furnace casing a hole is cast to receive a cast iron pipe C, which is bedded in fireclay in the bricks at one end, and enters a square cast iron box D upon which the pipe E rests within the brick stack. The pipe is slid in from the back, as seen in back elevation, Fig. 17, and in Fig. 18, plan section, and there is an air space all round between it and the brick, the idea being that it is cheaper to renew a piece of common cast pipe than to rebuild or repair a stack, and that the removal can be effected without delaying the work of a furnace. So, too, it is easier to renew the pipe C than to rebrick the outlet.

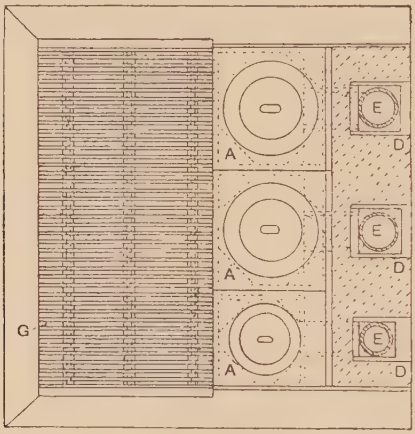


Fig. 18

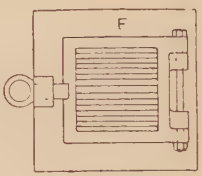


Fig. 19

There is a very good design of drop-bottom grate, which is in one respect an improvement on the ordinary method of inserting square bars of iron to be drawn out singly. The grate is a single casting F, seen also in Fig. 19, hinged to the bottom flange of the case, and is retained in place with a square draw bolt, which can be slid out by means of a bar thrust down from above, the end of the bar entering an eye in the bolt.

The grating G over the ashpit is formed simply. Bars of iron $1\frac{1}{2}$in. by $\frac{1}{2}$in. are threaded together with rods, three in number, passing through holes drilled in the bars, and having washers between. The gratings are thus built up in 3ft. lengths, convenient for lifting out by. They have the advantage of not being liable to fracture, as cast gratings are.

Carr's Portable Furnaces.—Carr's portable furnaces comprise several useful features. They are made in a wide range of dimensions to suit different requirements, and are employed in connection with a chimney draught. Their essential construction is shown in Figs. 20-23, in front and side views, and in vertical section and horizontal plan, while Fig. 24 is a special construction with draught holes in the sides.

The furnaces are built of plates of cast iron A, or when required for shipment abroad, of wrought iron. Bolts passing

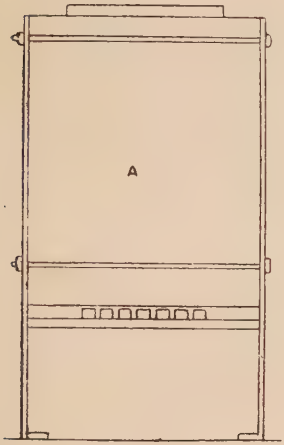


Fig. 20

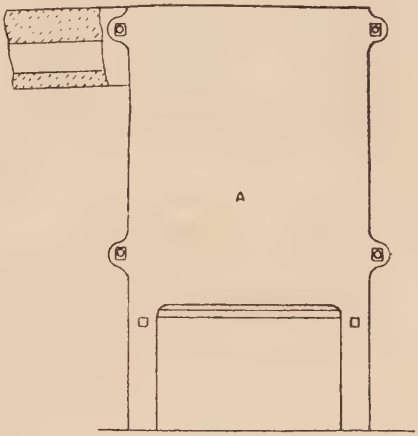


Fig. 21

through lugs on the cast plates hold them together. The brickwork is built in such a way that the furnace can be relined easily. It is carried on a cast iron plate B having a square hole, and resting upon flanges C, which are cast within the casing plates at a suitable height. A lining of sand or fireclay is preferably inserted between the bricks and the casing, in order to keep the latter cool.

A special feature in this furnace is the keeping of the firebars well below the bottom of the furnace, by which arrangement the pot is prevented from sinking. As the air for combustion enters mostly above the bars, the fuel there remains almost unburnt, and there is little chance of settlement of the pot, while around the pot the combustion is active. In fact, a solid plate may be used

instead of grate bars, or the latter can be placed close together, so forming practically a continuous plate. In such a case slots would be required in the furnace sides, as indicated at D (Fig. 24), for access of air. The usual construction, however, is that in which

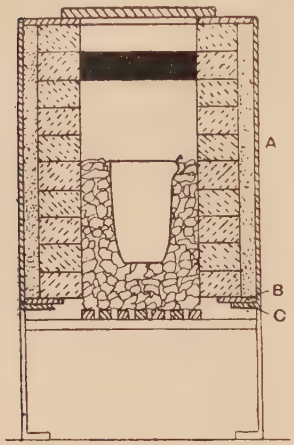


FIG. 22

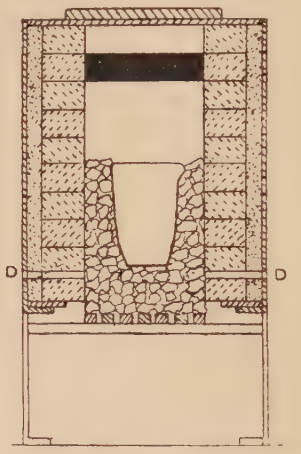


FIG. 24

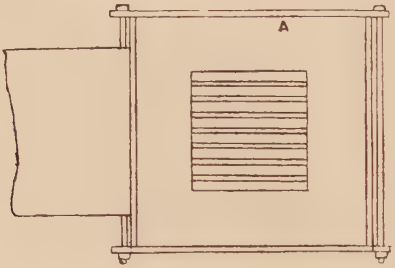


FIG. 23

air enters around and between the firebars below the brickwork. Solid linings are supplied with these furnaces when required. A 20ft. chimney, of 14in. by 9in. section, is an average used for these.

American Portable Furnaces.—Figs. 25-27 illustrate, in elevation, plan, and vertical section respectively, a square brass-melting furnace of the portable type, in which the casing is made of cast iron plates bolted together. The plates range from $\frac{1}{2}$in. to $\frac{5}{8}$in.

thick, and are bolted together with long bolts passing through lugs. Ledges are cast at A and B to support the brickwork. B carries the upper brickwork and divides it from the lower, which is carried by A. The lower is that which burns out most

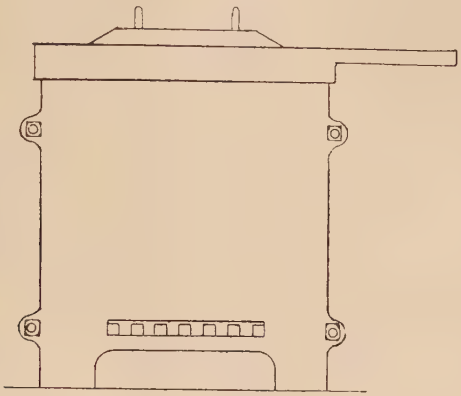


Fig. 25

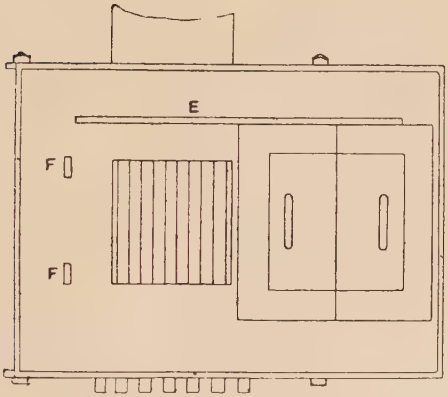


Fig. 26

rapidly, and by interposing the flange B it can be renewed without disturbing the upper bricks. A slot is cast in the front and back plates for the grate bars, and an opening is also cast in the back plate to the flue. The back and front plates are recessed below to form legs and to admit draught. The cover plate is of cast iron, and may either have a square opening, as shown, and as is

most usual, or a round one if preferred. The top is extended to one side in order to allow of room for moving the sliding cover out of the way without lifting it off. A guide strip E is cast to one side, and stops F, F at one end to facilitate the setting of the cover over the mouth. The cover is made in halves, and is lined with fireclay. The lining bricks are carried out underneath the top to protect the latter, as seen in Fig. 27.

Figs. 28-31 illustrate two circular brass furnaces of American design. The first (Figs. 28 to 30) is of sheet metal, the other (Fig. 31) of cast iron. With that exception they are of similar design, and may be made of the same general dimensions. In the case of the wrought iron or steel casing, an angle ring A (Fig.

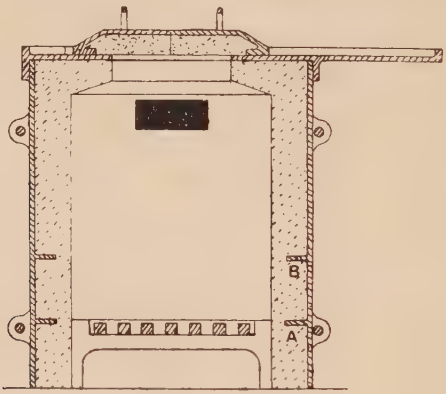


FIG. 27

31) has to be riveted round inside to afford support to the bricks. A slot has to be cut at the back and front to support the grate bars, and the angle A is fitted so that its bottom edge will be flush with the top edge of the slot. Pieces are cut out of the sheet in three or four places to leave legs for the casing to stand upon and for flow of indraught. A hole is cut near the top for the exit into the chimney. In the cast iron casing (Fig. 29) the metal is about $\frac{1}{2}$in. or $\frac{5}{8}$in. thick, the ledge A is cast, and also the slots for the grate bars. An opening is cast to the chimney, and portions are cast out of the base. In each furnace the top is cast separately, and is secured to the casing with hook bolts. It is necessary to cast the top separately from the body in the casing, because it may fracture and require renewal.

In reference to the carrying of the bricks underneath the top plate, as seen in Figs. 27, 29, and 31, the common bricked-up English furnace has no protection for the cover plate around the mouth and within the bricks. The plate becomes red hot, and besides causing much discomfort to the melter—who has to stand over it when examining or lifting the pot—it is very liable to crack. The plate is often left cracked, and the fracture does not extend farther, but the heat is always excessive during melting. In the furnaces here shown the bricks are made to overhang at the top, underneath the cover, to protect the otherwise exposed

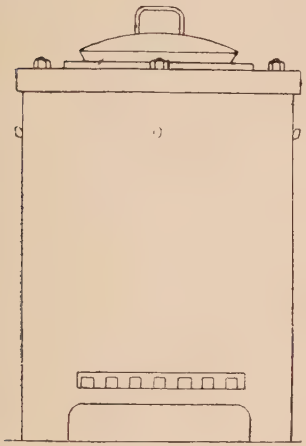


Fig. 28

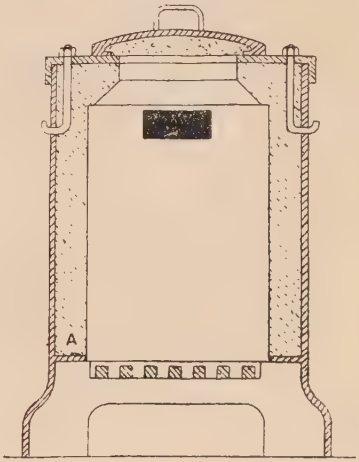


Fig. 29

faces, and it is thereby well protected. The round furnace is more favourably adapted to such an arrangement than a square one would be.

In England, the furnace cover is usually distinct from the tile, and both are generally castings. The advantage of this arrangement is that the cover need only be removed when charging the furnace or lifting out the crucible. For observing the progress of the melting the tile only is removed.

In America, the general practice seems to be to have only one cover. In order to lessen the labour of moving this, it is frequently made in halves, as in these figures, each half being slid to one side in order to open the furnace mouth. Sometimes a single solid cover is used, either flat or dished, but it is not liked.

In Figs. 26, 27, 29, and 31 the covers are in halves, very light, and protected with fireclay. They are arched and recessed to receive the fireclay. The same type may also be made in one casting. When made in halves, nails are cast in to confine the fireclay at the joint edges. A number of small holes are cast in the cover. These are to permit the escape of any gas which may be generated. A thin layer of very fine coke is laid between the fireclay and the cast iron, for the gas to collect among.

In American brass furnaces the cast iron tops are often cast with expansion slots, as seen in Fig. 30, and so are the rings which in cast casings support the brick. The idea is a good one,

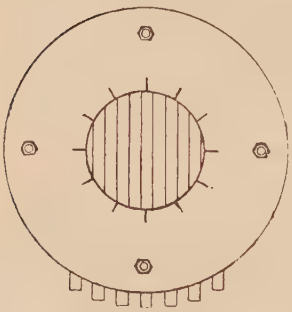


Fig. 30

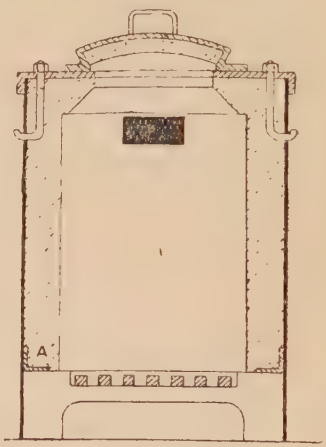


Fig. 31

since there are few cast iron covers which do not become cracked in time in consequence of the difference in the amount of expansion in the vicinity of the heated mouth (which is exposed to the direct flame of the furnace) and the portions away from it (which are protected by the brick and are comparatively cool). The slots are spaced at intervals of about 3in., and may be from 2in. to $2\frac{1}{2}$in. deep and $\frac{1}{8}$in. or $\frac{3}{16}$in. wide.

Fig. 32 illustrates an American portable furnace, similar, as regards internal arrangements, to those shown in the previous figures. But it is made in three pieces, the base A and cover B of cast iron, and the body C of sheet iron, riveted, the whole being held together with bolts running vertically.

The sizes of these furnaces do not vary much. They range from about 23in. to 30in. in depth inside measurement, and from 40in. to 48in. outside; from 14in. to 26in. square, or in diameter, inside the lining. Firebricks are used for lining; or solid Gautier lining.

Linings.—The brick linings and the loose grate bars of the English brass furnaces are very permanent features, to which few exceptions occur. We have noted such exceptions in previous illustrations, and also the fact that removable linings are employed to some extent in America. Fig. 33 illustrates one of these linings,

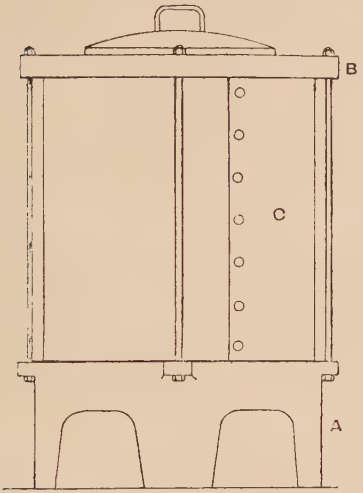


FIG. 32

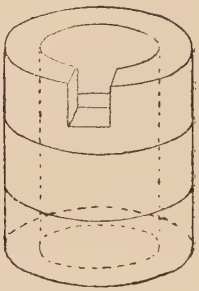


FIG. 33

which are made to suit any furnace. The advantage of these, is that of ready renewal, avoiding the loss of time involved in rebuilding a brick structure—a consideration when the number of furnaces in a shop is limited, and in which valuable time would be lost while a furnace was being rebricked. The removable lining is also better than the devices noted in some previous examples, of having a ledge to support the upper bricks distinct from the lower, so that the latter, which burn away most rapidly, might be renewed without disturbing the upper ones. A removable lining need not fit the cast or wrought iron casing closely, but an air space, or a space for a non-conducting clay or sand, might be left with advantage.

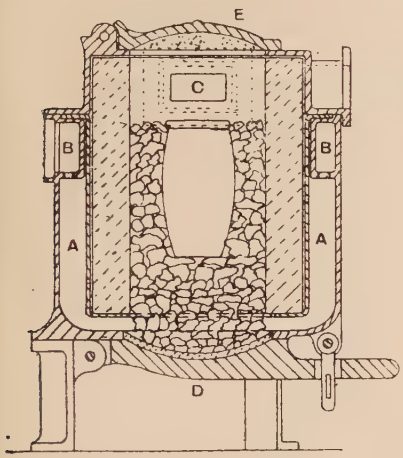
Drop Bottom.—The drop-bottom grating, too, is a device which occurs in modern practice. It saves a little time by comparison with loose bars, and when a furnace casing is built of metal plates instead of wholly of bricks it seems desirable that the drop bottom should be included in the design. Whatever economises labour and tends to order and cleanliness should not be despised in a shop.

Reverberatory Furnaces.—Reverberatory furnaces are used to a limited extent for heavy brassfounding. The advantage which they have over the crucible furnaces consists chiefly in the facility which they afford for melting heavy lumps of old metal, which in the ordinary course would have to be made red hot and cracked up with the sledge small enough to go into the crucible. It is also convenient in making heavy casts to melt the metal in one furnace instead of collecting the charges from several crucibles, which may cause delay and possible want of homogeneity. There is no hard-and-fast design of reverberatory furnace. The essential point is that the bed be made sloping to the extent of a few inches from the charging end to the tapping end. The size of charging door will depend on the maximum dimensions of metal which have to be introduced.

Blast Furnaces.—Fletcher's furnaces are different from ordinary brass-melting furnaces in the fact that they are constructed for blast, and that fuel is economised by warming the blast before it enters the furnace, and in some cases in utilising the waste heat for the purpose of warming crucibles and their charges previous to their insertion in the melting furnace itself. The results are remarkable, since in one particular furnace, gun metal can be melted at the rate of 120lb. in thirty-five minutes, with an expenditure of only 25lb. of coke. There are no firebars. The same furnaces can be used with or without blast, although built for the latter. They are entirely self-contained, but are, except the smallest ones, sunk into pits covered with gratings. The melting furnace and the heating furnace are not necessarily combined in one. The following is an account of the principal details in the construction of these:

Fig. 34 illustrates the essential furnace without the warming chamber. It comprises an inner iron shell, lined with firebrick or other suitable refractory material, and surrounded with an outer

shell of cast iron, leaving an air space A between the two. The inner casing is suspended on the outer, and the latter stands on feet of cast iron or of brickwork. The air enters a circular passage B, and passes round it and thence through holes into the annular



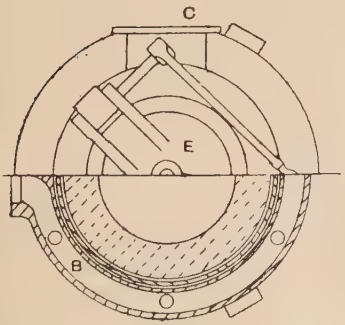


Fig. 34

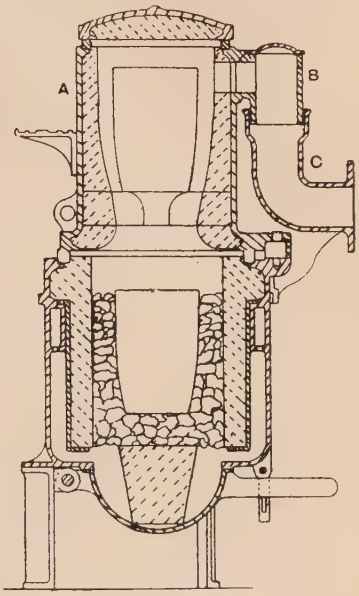


Fig. 35

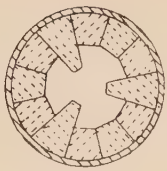


Fig. 36

chamber A, down to the bottom of the grate, and upwards out at the flue C. This fulfils a double purpose. The air is heated by its passage down the annular chamber, and there is little or no loss of heat by radiation from the casing, tending to cool the crucible. In another important particular the furnace differs from the ordinary brass furnaces with loose sliding grate bars: The

bottom D is solid, lined with a refractory material, and when the furnace has to be cleared at night the hinged bottom is dropped bodily, similarly to that of a cupola, and pulled up and cottered again in the morning. There is another advantage in this arrangement—namely, that if any metal gets out of the crucible, it remains in the bottom, instead of mixing with the ashes. The lid or cover E also is hinged and lined with a refractory material.

Preheating with Waste Heat.—In the furnace to which a heating chamber is attached (Fig. 35) the place of the cover is taken by the heating chamber, which is hinged upon and makes a close fitting with the melting furnace, and through which the waste heat from the latter has to pass on its way to the flue. The heating chamber A comprises an iron casing, lined with bricks, which sustain the heating crucible. The elbow pipe B which is attached to the upper casing swivels in another elbow pipe C, which is attached by means of a bracket to the furnace casing. The axis of the jointing of the pipes coincides with the axis of the hinge pin, so that the upper heating chamber can be moved aside from over the melting chamber without dislocating the joint arrangement of the pipes. The heated gases, therefore, from the melting furnace pass up around the crucible in the heating chamber, and thence to the flue through the elbow pipe. When the brass is melted in the bottom pot, the top chamber is swung aside, the metal poured, and the crucible taken out and put in the place of the one removed. Fig. 36 shows one arrangement of bricks for supporting the second crucible while being warmed.

In the Fletcher furnace, on account of the blast entering the furnace above the place where the metal would lie if the crucible were to fracture, there is no necessity in the event of such an accident to stop working. The metal can be removed at night when the dished bottom is opened to clear away the slag and take out the stand. All time usually spent in washing and smelting brass ashes is therefore saved by this arrangement. Much less than half the quantity of coke required in the ordinary fires for a given weight of metal is necessary in melting in this furnace. Small coke may be used if a start be given with a bottom of ordinary-sized pieces, thus utilising that which for general foundry purposes is useless. The certainty of the time in which metal can be melted is an advantage. If the outlet B is led into a chimney

stack, the furnace can be worked without a blast, thus obviating the necessity of suspending operations while the fan is not running. After using the furnace, in the event of another heat not being immediately required, it is only necessary to shut off the blast, take out the crucible, and close the lid; and the furnace will keep alight for several hours without the addition of fresh fuel.

The rapidity of melting with small quantities of coke is remarkable. Thus, 46½lb. of converted bar scrap steel were melted with

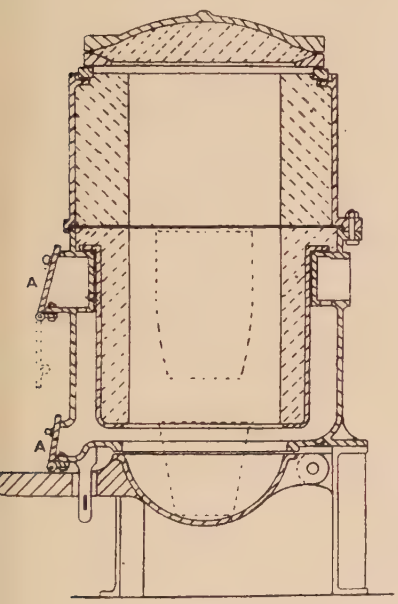


Fig. 37

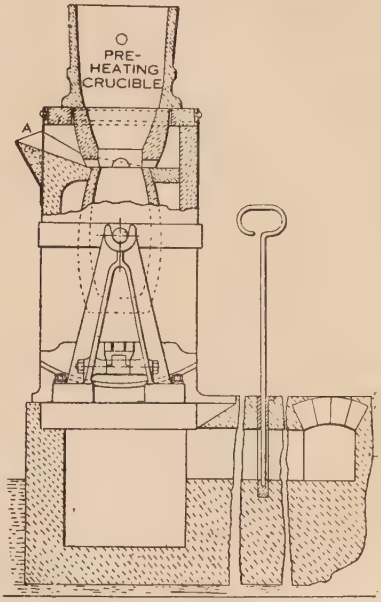


Fig. 38

64lb. of coke in 1hr. 54mins.; 60lb. of gun metal were melted with 14⅓lb. of coke in 25mins.: ten heats were made and the figures given are the averages; 97lb. of iron were melted with 84lb. of coke in 1hr. 42mins., 21lb. of which were under the crucible.

A modification in the Fletcher type of furnace is shown in Fig. 37. Its essential feature is the addition of doors A, A, lying at such an inclination against the openings which they close that they will remain in those positions under the pressure of a forced draught until the pressure exceeds that which is desired. If it

does, the hinged doors will open and relieve the pressure. The lower door also provides means for the removal of slag, dross, and ashes from the bottom of the furnace.

Preheating on the Piat System.—The preheater of the Piat furnace, Fig. 38, is a supplementary crucible above the melting crucible, but it is pierced with a hole in the bottom. Ingots and pieces of metal are heated in this way by the waste heat from the furnace below. The crucible is not removed from the furnace during its life, the pouring being done by tilting the furnace bodily, when the metal runs out through the fireclay spout A.

The Green System.—In the furnace manufactured by George Green & Co., of Keighley, Fig. 39, the blast is heated in an annular casing A, which surrounds the lower portion of the body of the furnace, and then passes up into the coke at the bottom. The blast is delivered to the belt by a Y-shaped pipe through the two trunnions on which the furnace is tilted for pouring. The top of the furnace is designed in the form of a combined charging hole and preheater, and is lifted during the pouring operation to the position indicated by the dotted lines, Fig. 39, being counterbalanced by weights. It is covered with a hood, not shown, to direct the fumes into the chimney, and the furnace has a drop bottom.

The Morgan Furnaces.—Some of the furnaces built by the Morgan Crucible Co., London, include, in addition to an annular air heating belt and the preheater for cold metal, an arrangement for heating the blast in its passage to the belt by the heat that is leaving the preheater in its course to the chimney. This would seem to be the last stage possible in the economy of the waste heat in a brass-melting furnace. A vertical section and plan of this furnace is illustrated in Fig. 40. The blast, entering through the nozzle, passes down the large blast pipe on its way to the furnace, which it enters through an annular air belt A, and through the fire bars. The belt is formed between the two shells of which the furnace is built. The outer shell is octagonal, the inner one being circular. The latter is lined with fire brick and is pierced with ducts or tuyers, in three tiers. The blast passes from the furnace into the preheater, without impinging upon the metal, and instead of being allowed to pass directly to the chimney it is conducted through a discharge pipe or flue, enclosed

within the blast pipe. The object of this arrangement is to delay the movement of the entering blast and to prolong its period of

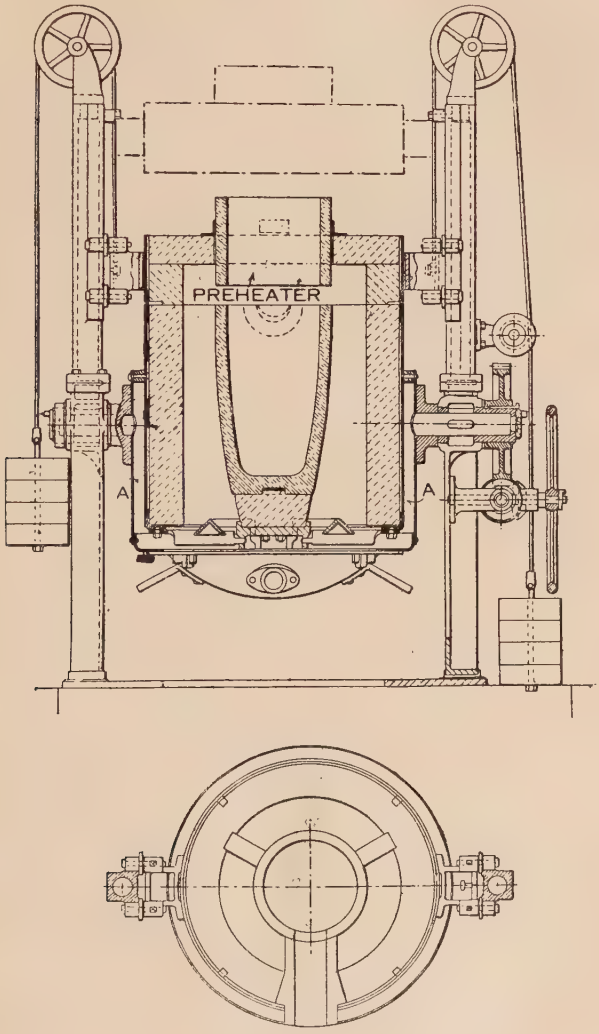


FIG. 39

contact with the waste heat escaping to the chimney. The blast has to travel in a spiral path coerced by the spiral cast on the

exterior of the discharge flue pipe, and occupying the space between it and the outer blast supply pipe.

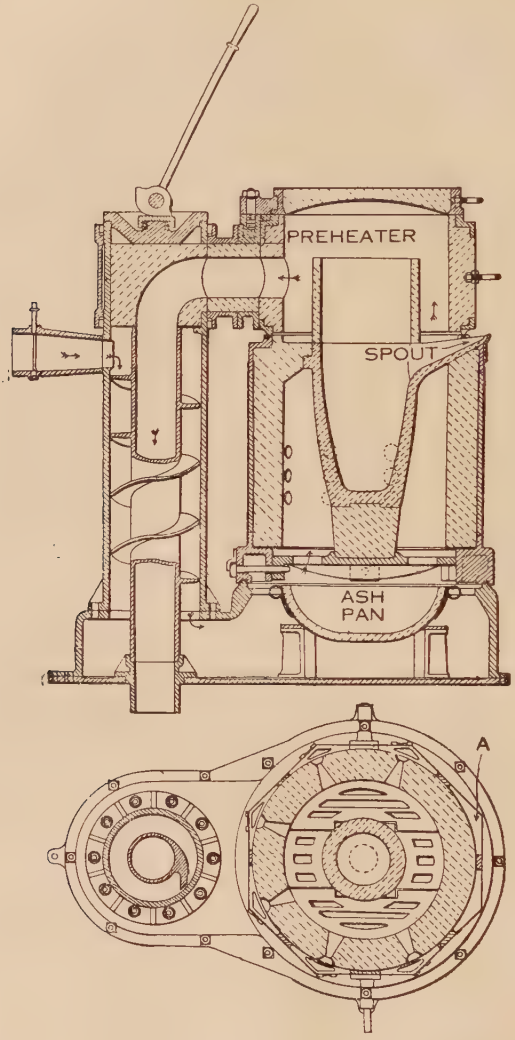


Fig. 40

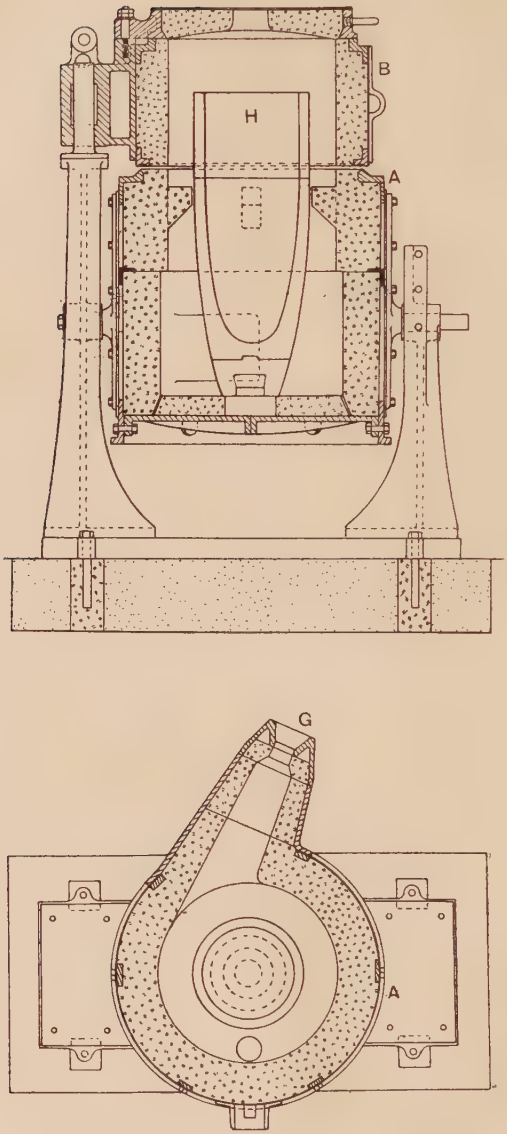
We are not here concerned with other details of these furnaces, but numerous good features will be noted in the illustration. A lever is provided, by which the preheater section is lifted off its

machined joint and swung aside. The hinged fire bars which are dropped when the day's melting is over, are locked in place by pins. The pan which catches the ashes, and the various tooled joints between the sections of the furnace, are noteworthy features. The furnace also is provided with a counterbalanced tilting gear.

Though brass furnaces are not of so great economical value and interest as the iron-melting cupola furnaces, and though they do not occur in nearly so great a range, yet these examples show in which direction improvements might be made in many brass foundries. At least it will be seen that designs are not stereotyped, that the common furnaces are not always the best, and that practice may be varied rather widely as best adapted to the conditions of different classes of foundries. Though the plain brick furnaces are by far the most general, yet the various other types which have been illustrated possess valuable features which are adapted to special conditions. And it is probable that the older brick furnaces will in course of time become less common by reason of the superior advantages of other types. It is interesting, too, to observe how similar ideas have recurred at intervals and in localities far apart. With the increasing employment of producer gas, its application to brass melting in large foundries may be reasonably anticipated, while the Fletcher furnaces permit of the use of gas in those of the smallest dimensions.

Oil Fuel Furnaces for Brass.—Oil fuel is now largely employed for brass-melting furnaces. It is one of the many phases of the present utilisation of oil for heating purposes. Its advantages are numerous, being in some respects similar to those which accompany the employment of oil in other furnaces, and in engines. The primary advantage is that little consumption of fuel occurs in the preliminary work of heating up, and little delay, since the furnace is started by the turning on of the oil, and soon attains its necessary temperature. And when a heat, whether long or short, is over, there is no waste of fuel surplus burning itself out. The temperature also is regular, no stoking is required, no cleaning out of ashes, no large fuel storage, nor transit of fuel to the furnaces. All these are points which should commend themselves to users of brass-melting furnaces.

The oil furnaces by the Morgan Crucible Company Limited, of Battersea, London, follow in the main the designs of the gas



FIGS. 41 and 42

and coke fired furnaces, constructed by the same firm, so far as the tilting and the preheating arrangements are concerned, but the drop bottom and ash pan are naturally omitted. One of these furnaces is shown by Figs. 41-43. The general construction includes the body A, or melting chamber, and the preheater B above, which can be swung aside by the handle C. The melting chamber is tilted for pouring with the gearing and hand wheel

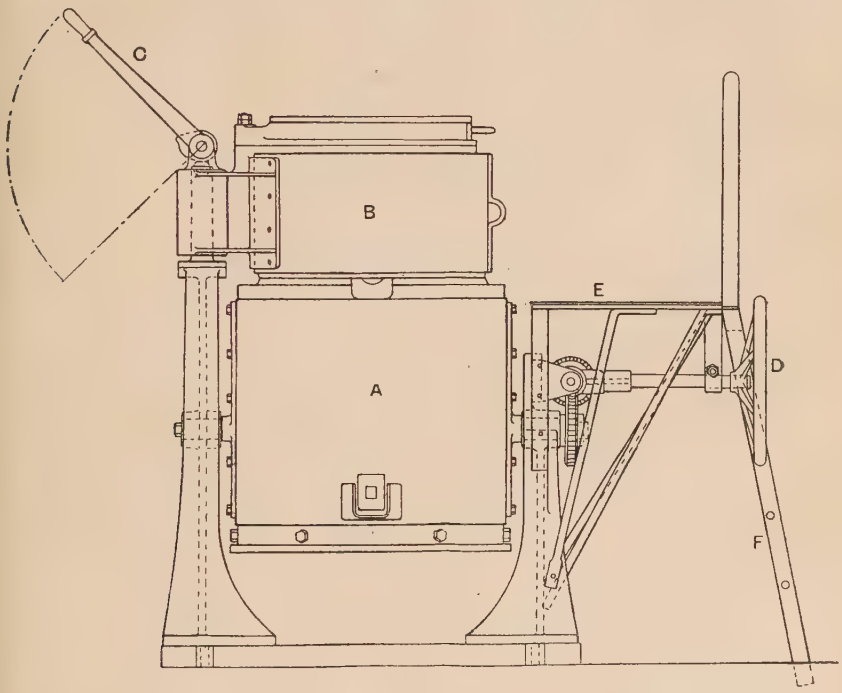


FIG. 43

seen at D. The crucible is inserted from the platform E, which is reached by a short ladder F. The oil is sprayed through a nozzle at the lower part of the body, coming in at one side at G. The following description gives the more salient details of this furnace:

The body A—of sheet steel—is carried on trunnions, and is brick-lined. The conical injector box G is attached to the shell, but the burner is fixed independently, so that when the furnace is tilted, the position of the burner remains unaltered. The pre-

heater B is a cylindrical steel casing, brick-lined. It has a cover which is pivoted to slide laterally to permit of inspection, or charging, and through it the waste gases are exhausted. It can be raised and swung aside by the lever C shown, which acts through a cam. When closed, it makes a tight joint with the body, and encircles a "Salamander" muffle ring H, which fits on top of the crucible. The function of this ring is as far as possible to prevent the gases, due to combustion, from passing over the metal. The supercharge of metal is thus protected from the flame, and from the introduction of sulphur or other elements of contamination. This is a precautionary matter of cardinal importance, since copper has a greedy affinity for the sulphur which is often present in commercial fuel oils.

The burners that are used with these furnaces are adapted for the low pressure system, which is preferred and recommended rather than the earlier high pressure system. The burner works with air, supplied at 12oz. per square inch (·05kilos. per cm.^{2}) or 20in. (500mm.) water gauge. In this system the bulk of the air required for combustion is supplied by the fan, or the blower, a portion up to one-third being induced from the atmosphere. The Morgan blowers can be employed for all furnaces, from aluminium, to steel and nickel heats. They are made in three sizes with different air capacities for the consumption of the fuel to be used.

High pressure burners are also supplied, when desired, in three sizes. In these the liquid fuel is completely atomised when it leaves the burner. One-third to one-fourth of the total air required is supplied under pressure. For ordinary brass melting the pressure required ranges from 20lb. to 25lb. per square inch (1·4 to 1·75kilos. per cm.^{2}). For steel or nickel temperatures the pressure is increased to from 30lb. to 35lb. per square inch (2·1 to 2·5kilos. per cm.^{2}). But for these high temperatures specially designed furnaces are used.

Any oil nearly may be employed. With regard to the selection of these, the Morgan Crucible Company say: "The residue obtained from gas works where oil is used for the enrichment of the illuminating gas, or one of the many distillates of petroleum, shale, creosote, or asphalt (if not too viscous) are all suitable. Liquid fuel, such as the carburetted oil gas tar obtainable from

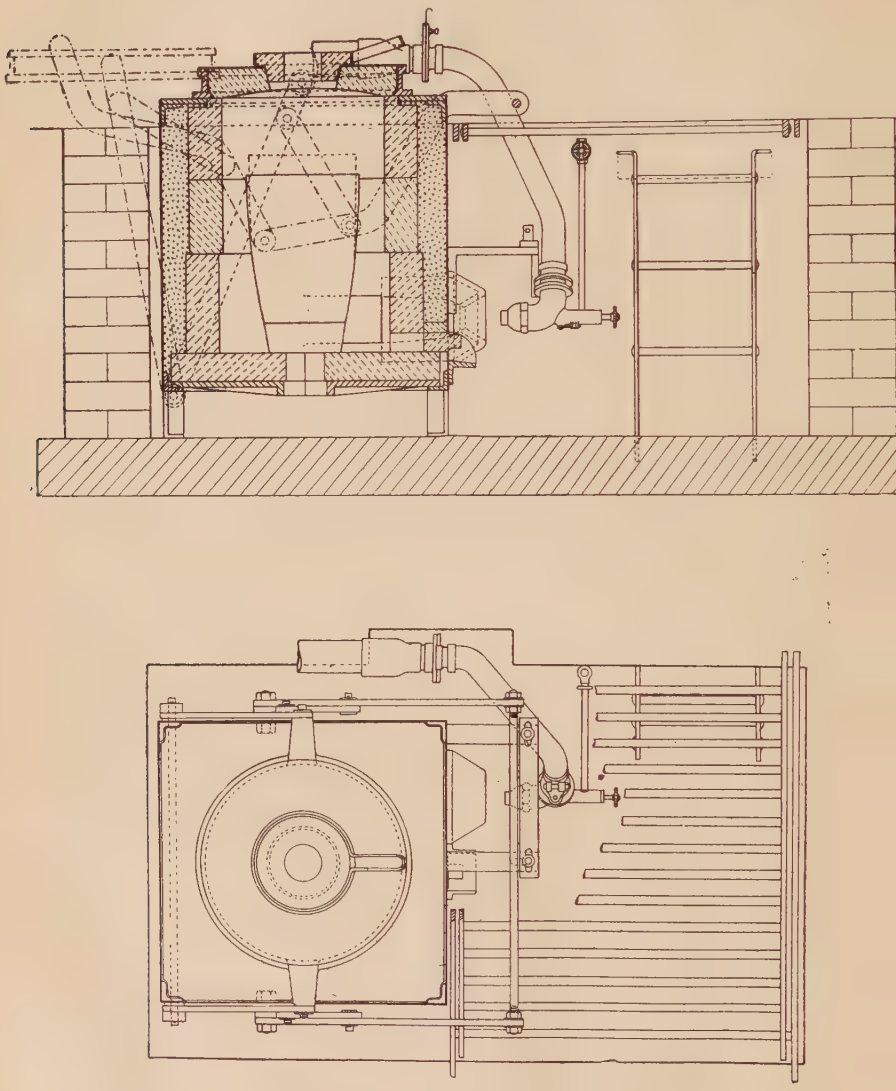
many gas works, has a sp. gr. of 1·9 to 0·9, runs about 240 gallons (910 litres) to the ton, with a calorific value of roughly 9500 calories per kilogram, or 17,100 B.T.U. per lb., and normally costs from 2d. to 3d. per gallon (4·54 litres). Low grade oils can often be obtained at a lower price. The oil should not contain more than 2·5 per cent. of water, otherwise its heating value will be greatly impaired, and the crucible will be at the same time exposed to a damaging atmosphere. Where this water content is exceeded to any considerable degree, settling tanks should be arranged in which to draw off the excess. It is essential that the oil should be atomised or pulverised so as to obtain the requisite combustible mixture with the air, and for this purpose the special burners (already described) have been designed to work respectively under high or low pressure."

The tilting oil furnaces are too heavy for the requirements of the smaller foundries, taking from 350lb. to 450lb. of metal in a charge. To meet the demands of shops where small quantities are melted, the "lift-out" crucible furnaces (Figs. 44-47) are designed, constructed in three classes, and for oil only. The three groups take one crucible only (Figs. 44 and 45), two, or more crucibles (Figs. 46 and 47) in one common melting chamber, and four or more crucibles in separately controlled chambers. The chambers in these are square or oblong box-like casings, brick-lined, provided with covers, a fuel burner or burners, and a flue, the furnace being so absolutely enclosed that no fumes can escape into the foundry.

Of the three, the separate chamber design for four or more crucibles with only two burners is the most generally useful, resembling the usual battery type in which any one crucible can be inspected, charged, heated or stirred, without interfering with its neighbours, or affecting the temperature over the rest of the block of furnaces. These lift-out designs take in their extreme ranges crucibles from 30lb. to 200lb. capacities.

In installations of oil fuel furnaces sundry necessary precautions have to be taken. The oil storage tanks are the first item in the plant. These include main storage reservoirs, and branch service supply tanks to serve individual ranges of furnaces. The latter are made of galvanised iron to hold respectively 50, 100, 150 and 200 gallons of oil. A tank contains two perforated metal

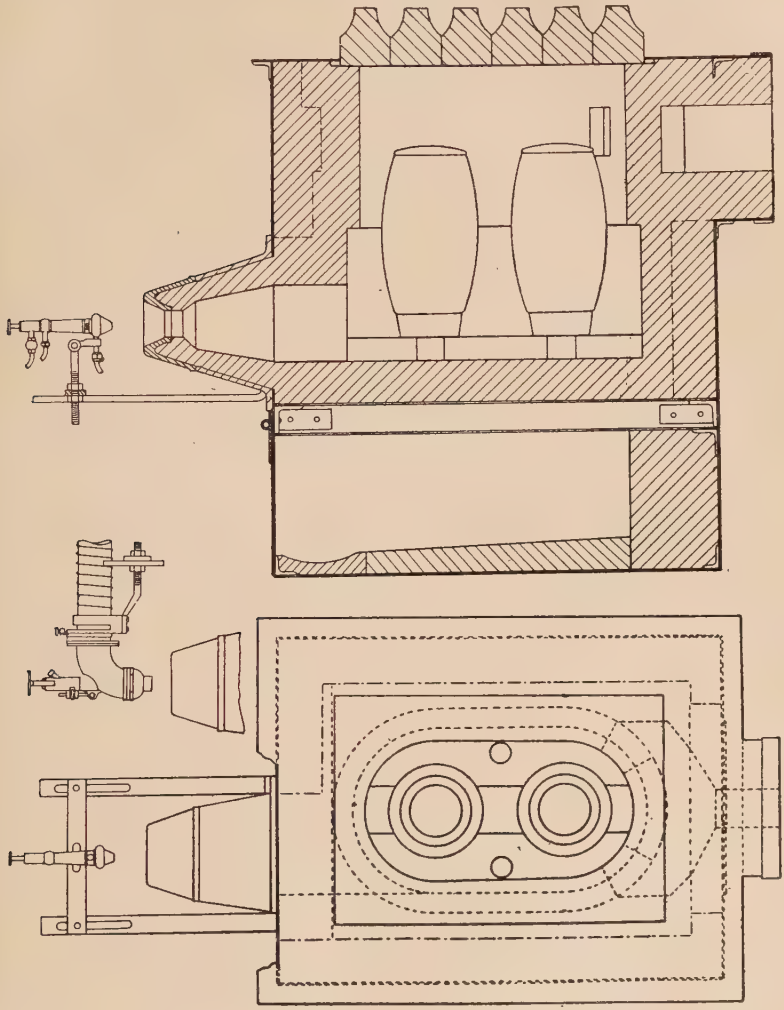
screens in vertical frames, one frame being fitted with a coarse, and one with a fine mesh screen. There are also two level gauge



FIGS. 44 and 45

glasses with stop cocks, an outlet connection with a screw-down valve from which the main supply pipe is run (a 1in. pipe is

generally sufficient for several furnaces), a wooden top cover, and two 1in. draw-off sludge cocks. The oil supply tank should be

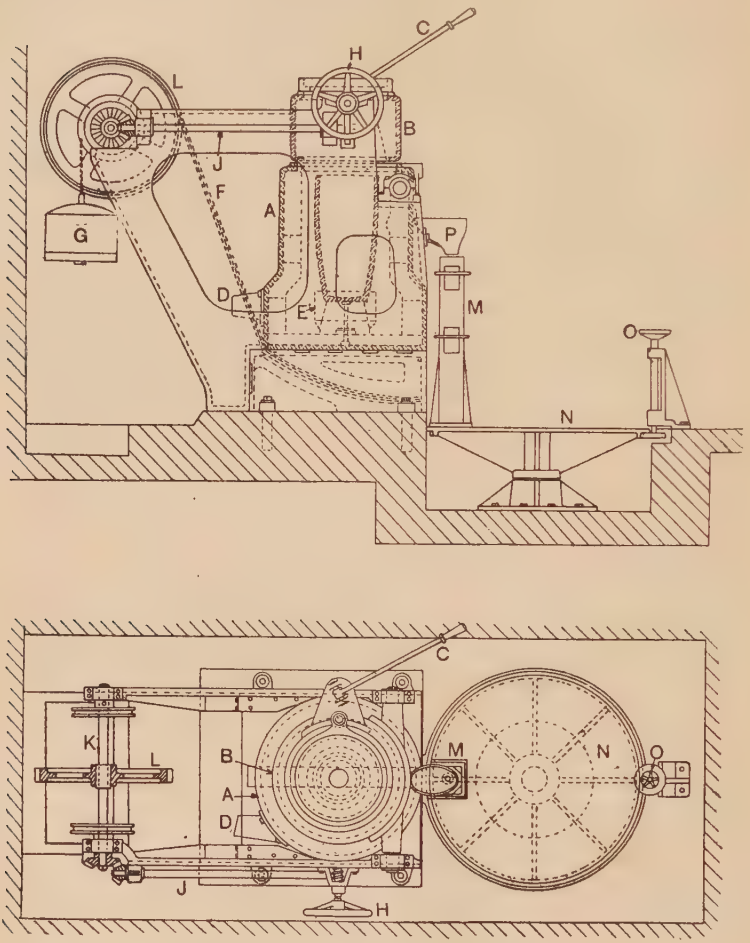


FIGS. 46 and 47

located as near to the furnace as possible, and placed at a height of about 10ft. above the oil burner.

If a high pressure burner is used, a supply of compressed air is required, for which a specially designed air compressor is built.

The air receiver is preferably placed at the furnace end of the pipe line, and the pipes should be arranged with a fall into the receiver, which will then collect condensed water, to be drained off by a cock provided for that purpose.



Figs. 48 and 49

If a reducing valve is fitted on existing high pressure air mains, a pressure gauge should be provided on the furnace side of the valve. Any closed vessel of about 10 cubic feet capacity, capable of withstanding the air pressure, can be used as a receiver. No

air receiver is necessary with low pressure burners unless the air supply is very unsteady. Fans are used for the low pressure oil burners, being either driven by belt, or electrically, having the motor enclosed in the housing cast with the fan casing. They have aluminium impellers, mounted on a steel shaft, running in ball bearings.

The tilting furnace patented and built by the Monometer Manufacturing Co. Ltd., of Birmingham, is shown by Figs. 48 and 49, as designed for oil firing. The same broad design is retained for gas and for coke firing, with the necessary modifications that are required to adapt it for the use of either fuel. The broad design comprises the following:

The body A of the furnace is a cast iron casing, this being preferred to thin sheet, as being more massive and considered more durable. It is lined with firebrick of considerable mass, and interchangeable for convenience of re-lining. It is of the tilting type, being carried on trunnions located in such a way that the pouring point P is always at a constant position, so that the entire contents of the crucible can be poured into a hole as small as 1in. without moving the mould.

The body is surmounted by a preheater B, which can be raised and swung aside by a lever C and cam during charging and pouring. The joint between the preheater and the body is a socket and spigot, made in segments, past which flame cannot escape. These segments are interchangeable.

The operation of the furnace is as follows. The flame from the burner, fitted at D, Figs. 48 and 49, is directed into a spacious annular combustion chamber below the crucible, against a stand E, so avoiding a cutting action against the crucible. The oil burners require a supply of air under a low pressure of not less than 1lb. per square inch for light oils, and 2lb. for heavy oils, for which a blowing fan is supplied. For batteries of furnaces, pipe lines for oil and for air are conveniently arranged above, and to one side of the furnaces. Oil supply tanks are provided of suitable capacities of 100, 200 and 500 gallons. These have an oil level gauge, a strainer, an outlet cock, a filling hole, and a cleaning-out hole. Fume extraction piping may be used, connecting to a conical hood over each furnace.

The tilting apparatus is of an efficient design, a plate chain

F being used. In addition, the movement is geared down, and the load is counterbalanced by a weight G. A handwheel H at one side has a worm on its shaft that turns a wormwheel on a shaft J running horizontally, and which carries a bevel pinion at its farther end. This drives a bevel gear on the tilting shaft K. About the centre of this shaft a large wheel L is keyed, to which one end of the chain F is fixed, the other being fastened to the bottom of the furnace on the front side. It will be seen from Fig. 48 that a curved guide piece is attached to the bottom of the furnace body, the curve being struck with a radius from the trunnion centre, so that the chain remains in contact with the guide in all positions as it is pulled by the turning of the sprocket wheel. Also that the pouring point P, the spout being close to the trunnion, will fill a mould brought directly under it.

In the illustration, an adjunct is shown under the pouring point for casting brass mixtures into bars ready for cutting off into fuse billets. This is a divided mould M of cast iron with encircling clamping rings and wedges, long enough to cast bars in 40in. long, and which are of any diameter, from $\frac{7}{8}$in. to $2\frac{1}{2}$in.

As the lip P of the furnace remains in a constant position during pouring, the moulds made elsewhere are brought to the turntable N seen in Figs. 48 and 49 and moved round underneath the spout to be poured, and thence away. The turntable is 4ft. 8in. diameter (in some cases 9ft. diameter), is carried on a ball bearing race, and is turned by a handwheel O, the shaft of which carries a pinion engaging with a ring of teeth on the edge of the turntable. The teeth are protected by the extension of the table to form a covering flange.

The Rockwell oil burning furnaces are used very extensively in America. These also are tilted for pouring without removing the crucible. Otherwise they differ in nearly all details from the English designs of furnaces. (*See* Fig. 50.)

The combustion chamber is either single or double, the latter being preferred for the larger melts. The explanation is, that as it is better to melt in a single crucible when a large body of metal is required than in several smaller ones, quicker melting is ensured by employing a large combustion chamber, than having small annular spaces immediately round the crucible.

The furnace is tilted by means of the handwheel and worm gear at the right. The supplies of oil and air are brought through one of the trunnions, A being the pipe for oil, B that for air, and led through the top of the furnace at C to be distributed downwards into the combustion chamber, whence the flame circulates round the crucible. The tilting of the furnace, therefore,

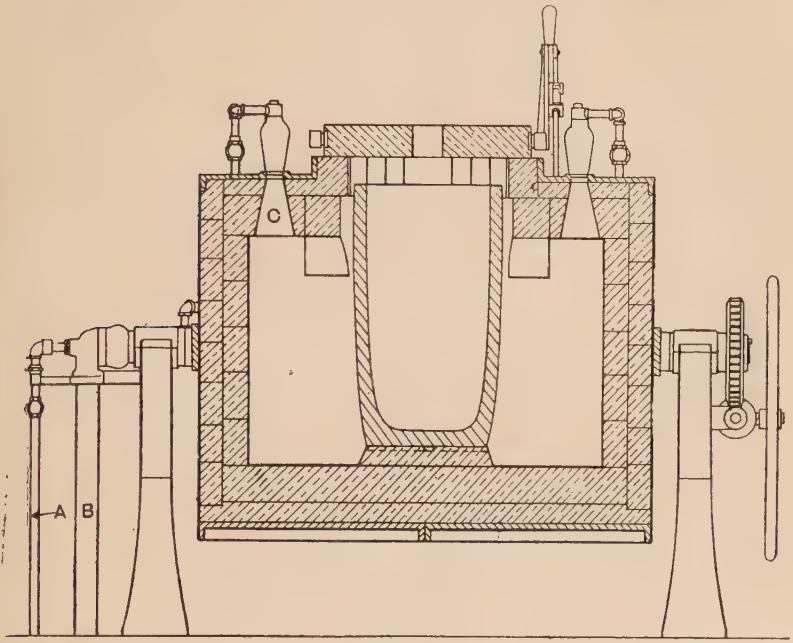


FIG. 50

does not disarrange the relation of the parts. A fire tile, bonded with iron, forms the cover, which can be tilted by means of a lever.

The furnace body is of sheet iron, bolted to top and bottom flanged plates of cast iron. The firebrick lining is in two thicknesses, forming a good body for the retention of heat. Only the inner lining ever requires renewal.

The Schwartz furnaces, also American, resemble small converters, in that no crucible is used. The metal is melted enclosed only in the firebrick lining, under blast brought in through the trunnions. The furnace is tilted and poured from a spout at one

side. Charging is through the top, covered with a hinged door. The bottom is removable.

Crucibles.—From twenty to thirty years ago the clay crucibles only were employed in the brass foundries. They caused trouble by cracking, and so letting the metal out of the pots, or crumbling when being gripped by the tongs. Since the plumbago crucibles have been introduced, those of clay have nearly disappeared from the brass foundries. The "salamander" brand of the Morgan Crucible Company, of Battersea, has earned a well-deserved reputation.

Annealing.—Crucibles are always annealed previous to use. They are placed in the furnace, mouth downwards, in a fire not too hot; when thoroughly warmed they are turned mouth upwards. The plumbago crucibles do not absorb moisture like those of clay, and once annealing suffices; neither are they liable to be cracked by frost.

Not only is this precaution taken, but it is well to warm them up before each time of using. This is done either by standing them on the furnace cover when this is red hot, or by placing them mouth downwards on the fire when newly lit, letting them remain there until the fire is clear, by which time the crucible will be warmed thoroughly. The reason for this is the absorption of moisture by the porous materials of which the crucible is made, and which causes flaking off or cracking to occur on the too sudden application of heat. The gradual warming up drives the moisture off. It follows, therefore, that more care must be taken to dry the crucibles in damp weather than in dry, and the drier they are kept when in the foundry the better. It is usual to place a shelf just above the brass furnaces, and to range the crucibles on it; this will be the hottest place in the shop.

The first thing to do after a furnace is lit, and before it is burnt up clear, is to put the crucible on top of the fuel, mouth downwards, to warm it up; if placed the other way, where the thickest material is, it is likely to become cracked. When heated, it is turned mouth upwards and charged, either in or out of the furnace. The mouth is then covered with a large lump of coke, coke filled all round it nearly to the top of the furnace, and the tile put on, remaining until the founder judges that the contents of the pot are melted. When melted, oxidation is prevented by throwing charcoal dust on the surface, or broken glass.

Coke.—Gas coke is used sometimes for brass melting, but the heat given out is not so intense as that of furnace coke, which is the proper fuel to employ. The furnace coke is the same as that which is used for melting iron. It is hard, heavy, silvery, clean, and though more expensive than the gas coke it is in every way preferable.

Magnetting.—Iron becomes mixed with scrap brass in the form of turnings and chips, and in scrap in which pins, rivets, and screws occur. It is necessary to remove this, as its presence would render the brass spongy. For turnings and chips a row of magnets are used, either by hand, or arranged in a machine. Machines are used for this purpose in large foundries. The magnets pick up the iron, which is brushed off, and the magnets and brass again brought into contact, the process being repeated as long as any chips remain. Before melting scrap, it should be carefully overhauled and iron parts removed by breaking up to facilitate their removal. White, or anti-friction, metal is often found in holes in the faces of locomotive slide valves, and in bearings. This also should be melted out.

Sands: Green Sand.—This occupies by far the largest place in foundry work. In the first place, it serves excellently for perhaps quite eight-tenths of the total work done, and is easily manipulated. It affords a cheap method of working, because when a mould is made, no further drying is necessary except in some few cases, and then only a mere skin drying. It is convenient, because a large range of mixtures is obtainable, ranging between weak and strong for lighter and heavier work, and for different sections of the same mould, subject to less or greater pressure. Green sand mixtures have features in common, as follows: They are loose, and are rammed green or moist; they are not dried, the moulds being poured into, without change of condition from that in which they were rammed.

Mixtures.—The suitability of mixtures, each for its own special line of work, depends on three main conditions. These are the character of the mixture, as determined by the proportions of the open, loose and free, or close and clayey character of its constituents, without reference to these qualities being a result of chemical differences; by the amount of water present, and finally by the manner and degree in which the ramming and venting

are done. Only a moulder perhaps fully understands in how large a degree the soundness and smoothness of the skin of a casting are dependent on these two conditions. Too loose ramming entails lumps, too hard ramming, scabs. Insufficient venting in almost any case results in blows and sponginess, and the harder a part is rammed, the more freely should venting be done. The few exceptions to the need for venting only occur in small moulds made of very open sands.

Green sand mixtures are rammed chiefly when enclosed in boxes. The box filling is old sand which has been used over and over again, having been turned out of the boxes after casting, and re-watered and mixed for repeated service. New sand, a facing sand mixture, is rammed directly against the pattern, and the old or floor sand is used for filling up, hence termed "box filling." The facing sand only occupies from about 1in. to 2in. thickness, increasing with the dimensions of the mould. It contains ground coal dust or charcoal to prevent sand-burning. The carbon ignites and burns away, leaving the sand honeycombed and porous, while the gas generated forms a film interposed between the molten metal and the sand.

The reasons why green sand moulds are not of universal application are: First, the sand, though rammed, is too loose and weak for some moulds in which numerous sections stand out in cantilever fashion, and are thus liable to become broken off and washed away by a heavy flow or rush of metal. Much assistance can be afforded such sections by rods and nails, but their use is often too limited to be reliable. The larger the mass of intricate moulds the greater are these risks, and although a strong mixture of sand can be used in such moulds, the body of which would be rammed with ordinary sand, the risks of wasters are too great to be taken. This being the case, green sands are wholly discarded for another material.

Another thing, entailing some risk in green sand work, is the presence of a large number of cores. The risk is cumulative, the numerous cores and vents being liable to cause trouble in addition to the mould proper, due to the large aggregate amount of gas generated in pouring. Again, where the risks of actual wasters may be slight, there are others, such as lumpiness of surface, general or local sponginess, roughness of skin, and slight scabbing

of castings, which founders of repute do not like to send out, and which many inspectors would condemn. In face of such risks it is better to abandon green sand and employ a rather more expensive way of moulding.

Dry Sand.—This is a strong sand mixture containing horse manure. When dried, it is hard in mass, though rather fragile in weak sections. It offers a firm surface against the pressure of metal, and little gas is developed at casting, because the moisture of the water used in mixing is dried out in the stove before the metal is poured. It is, therefore, a safe mould, though more costly than green sand, due to the necessity for drying it.

The differences to be noted in the working of dry sand, besides that of drying, are of three kinds. First, the ramming must be harder, as hard as can be done. Second, the venting is supplemented and helped by the burning out of the particles of hay in the horse manure during the drying of the mould. Third, the joints must be finned, *i.e.*, pressed down with the trowel after delivery of the pattern, and before drying, for unless this be done, the joints will be crushed and will fracture on closing the mould. Such a contingency does not occur in green sand, because it yields slightly, but dry sand is too hard and rigid to yield. Finning the joints has the effect of throwing the sand adjacent to the edges out of actual contact, and a very slight fin results in the casting, but this is of no consequence.

Finer sand is used for moulding light brass work than for heavy. In ramming heavy brass work the fine sand used for small moulds would be too close, and might cause scabbing. As in heavy iron castings, the sand should be of a coarse texture. But if coarse sand is used, fine facings will help to produce a fine skin on the castings. Flour mixed with the sand will produce a fine facing. Different portions of the same mould must be rammed and vented differently. The sand which comes next the floor in heavy brass-work must not be rammed so hard as that in the sides and top. If it is, the vents will not get away properly.

Dried moulds are favourable to the production of sound castings. They will not ensure them in the absence of care in other ways, but when everything else fails to produce sound castings the dried mould may be the one thing lacking. The advantage of a dried mould, like a dried core, is that the hot metal has little

moisture to act upon, and therefore little hydrogen gas decomposed from the water can be disengaged. Porosity of castings may be due to dirt in the mould, or to improper mixing and fluxing of the metal, and drying the mould will not prevent that; but it will go far to prevent that which is due to the disengagement of the hydrogen from the oxygen in water. The latter burns and forms a chemical compound with the metal, producing a hard skin on the casting; the former becomes occluded or dissolved in the mass of the metal, and in the effort to disengage itself as the metal cools it forms the familiar air bubbles. The same phenomenon occurs in steel, only worse than in brass or iron.

Loam.—Loam moulding occupies a sphere which is narrowly defined. With very slight exceptions it is retained for work mainly cylindrical or circular which is too large to be made from a pattern on account of the cost of the latter. There are, of course, fittings more or less numerous, not circular, such as feet, flanges, and the like, for which pattern parts have to be made. The main cylindrical or circular sections are swept up with boards, against loam plastered on and sustained by brickwork. Loam is daubed and built against the fittings, which are also supported by brickwork built to their outlines with the necessary loam clearances.

Loam is also used for sweeping-up large cores around a vertical axis against brickwork, also for cores on a horizontal axis, laid around a central core bar, with hay or straw ropes to bind the loam together, and to make up thicknesses. Often the thickness has to be made up in some sections with plates threaded on a central bar, and having the interspaces filled with haybands and loam. Again, loam is used for sweeping-up patterns to be moulded in green or dry sand. This is done when work is too long and too small in diameter to be swept-up on a vertical axis. Loam patterns may be plain, but much more often they carry fittings of wood, just as though the main body were of wood instead of loam.

Loam is of one mixture, but is ground and sieved coarser or finer according to the location in which it is to be used. Coarse loam is employed for roughing, finely-sieved loam for finishing coats. All loam contains quantities of horse manure. A strong sand is used mixed with water, and dried thoroughly in a stove. Usually it is self-venting, but awkward corners and angles are vented with the wire.

CHAPTER III

APPLIANCES

Moulding Troughs.—As a brass foundry does not require a deep sand floor like an iron foundry, and as the moulders chiefly work on benches and use comparatively small quantities of sand, moulding troughs are provided to carry the sand, and usually also to work upon. Another arrangement consists of a long moulding sand trough down the centre of the shop, and a long bench or

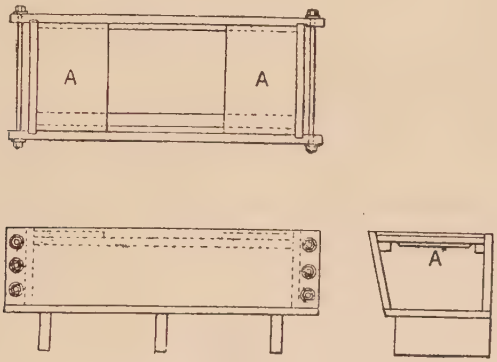


Fig. 51

benches down the sides. The men take the sand from the trough and pile a small heap sufficient for their requirements on the work bench. In the small shops the moulding trough, Fig. 51 or 52, is mostly used. It consists simply of a framed wooden box built against the wall, and sloped back at the front so that the moulder can work close against it. The top is made of a loose board or boards, A, sliding on ledges to permit of getting at the sand beneath. The flasks are rammed on this board, which also carries the small tools, the water-pot and swab, lime and flour bags, nails, and the rest.

Brass is valuable, and therefore the method of pouring into flasks on the floor, as in iron casting, is not so often adopted, save in the case of heavy work, as pouring with the flasks leaning against a spill trough. When the mould is full, any drops that run over fall into the trough, whence they can be collected without loss.

Boxes.—Moulding boxes are generally destitute of bars or stays. For heavy work they are similar to those used by iron-founders. The use of boxes without bars has given occasion to the bevelled and ribbed types of recent years, which are superior to those having parallel sides, because there is no risk of a drop-

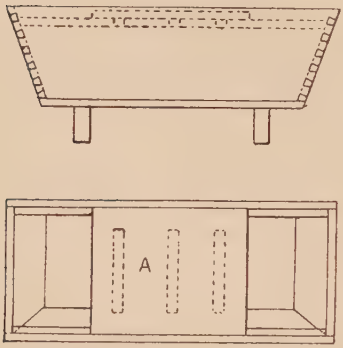


Fig. 52

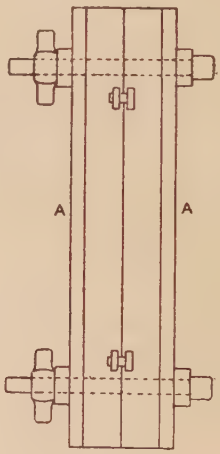


Fig. 53

out of the mould occurring. But a large volume of brass work is moulded in wooden boxes, which are poured edgewise, and this alters the arrangement of runners and ingates, and introduces the boards and cramps seen in Fig. 53. When a mould is poured edgewise, the sand is supported against the liquid pressure by the back boards A, A, which are clamped to the outer faces, while the mould is laid against the spill trough or other convenient support during pouring through the ends. A further economy is afforded by laying several similar moulds side by side, and securing them all with two long clamps embracing the whole.

The nomenclature of moulding boxes varies. Some men always call them boxes, others term them flasks. It is a matter of locality. Generally, the term flasks is used more by brass founders, and

boxes by iron moulders; but the two mean the same thing. Top and bottom flasks mean the same thing as cope and nowel—terms also used by men in different localities. Drag is synonymous with nowel, and with bottom part. Cope and nowel are names commonly used in America.

Some foundries are alive to the fact that good work cannot be reasonably looked for with badly-made flasks; others have not yet learned this very obvious lesson. Ramshackle boxes with unplaned joints and loosely-fitting pins are still common. It takes more time to make moulds in these than in those that are well fitted, and there is no certainty that the castings will not show bad joints and fins. When boxes are fitted with loose pins the only way is to give the top part a twist on the bottom at the time of ramming, and the same twist when closing for pouring. This brings the pins over to one side of their holes on cross corners, and ensures the relative positions of the two being alike when pouring as when ramming. Frequently a little wet loam is smeared on the edges of the flasks at cross corners, and two or three lines made across on this from the top to the bottom box with the edge of the trowel, as a guide by which to return the boxes into place. Such are the devices which have to be adopted when flasks are badly fitted. They occupy time, and the results are not so reliable as when the pins are fitted properly. Another point is that joints should be planed or milled to make a close and level face, otherwise the sand will be liable to become crushed at the time of clamping or weighting, and, moreover, without true edges there is no guide by which to strickle off level sand joint faces. Grinding is sometimes adopted, but milling or planing is preferable unless the grinding is done very carefully and on a suitable machine.

Box Stays.—To understand the shapes given to the boxes used by brass moulders, we must remember that bars or stays are not used for the bulk of their work. The exception is in the case of heavy castings, for which boxes just like those used in iron foundries are employed. For the most part, boxes measuring from 12in. to 24in. square, or 24in. by 18in. oblong, speaking roughly, will include by far the greater part of the brasswork done. Now, if these were fitted with crossbars, the bars would render them unsuitable for general work. If a set of boxes is made specially

for a certain piece of work and no other, then bars may be inserted if found desirable. But as a very broad rule, flasks for the brass foundry have to be made for general service. Then they must be formed like the middle parts of iron moulders' boxes, without any bars. The difficulty then is to retain the sand. In middle parts this is assisted by internal ledges which help to hold it, and which are often utilised to carry rods laid diagonally when the shape of the work permits of it. In brass moulding even this assistance is not available, but in the average box the cohesion of the sand alone retains it in place. The smaller the flask the less risk there is of a drop-out occurring. With increase in area the risks increase. The more the area is occupied with deep moulds the less will be the cohesion. The figures here given represent various boxes in common use, from which the reasons of their forms will be apparent. The risk of a drop-out occurs, it must

FIG. 54

be remembered, chiefly in the top or cope, or in the act of movement of the bottom part. Once the latter is on the ground there is no further risk. A top may fall out in the act of lifting, or subsequently, after it is set in place for pouring, and therefore no risk of the occurrence of such an accident must be run.

Taking the section of the ordinary box used for iron moulding and heavy brasswork, Fig. 54, the sand in the top is so divided up into narrow sections that it is well sustained by frictional contact with the bars, in which, however, it is often assisted by lifters hanging from the tops of the bars. This assistance is of value, because the bars are tapered and bevelled, and therefore slightly favourable to a fall-out occurring.

Retention of Sand.—The common box of the brass moulder having no bars, it is clear that with increased area risk is increased, the danger of a fall-out being much greater in a flask of, say, 2ft. square than in one of a foot square, supposing the depth to be the same in each case. Since by far the greater part of the boxes used have parallel sides without stays, the inner

faces are often roughened with shallow ribbings, produced by hatching over the box mould with a trowel or wire, a device

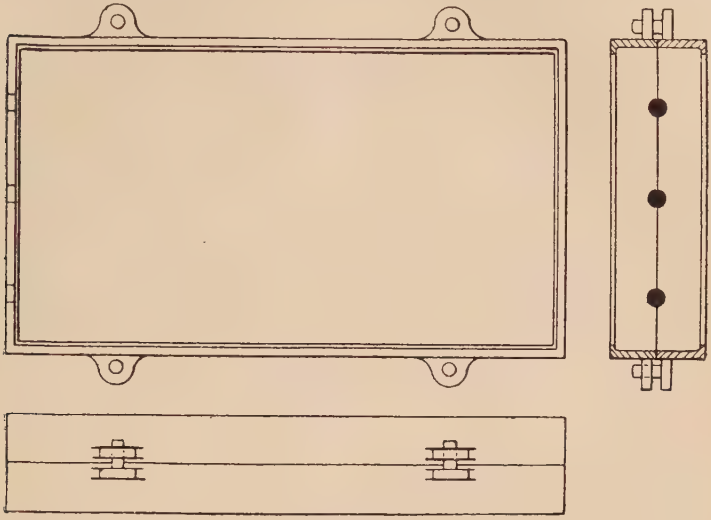


FIG. 55

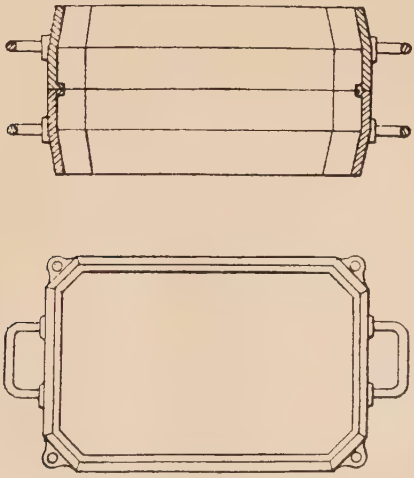


FIG. 56

which materially assists in the retention of the sand, especially when the inside faces are swabbed with clay wash. Fig. 55 is a brass moulder's typical flask with shallow ribs on the outer faces

to assist in holding the sand. Often the ribs are also placed next the joint face. The holes in the end of the box are utilised for pouring work on end.

A common type of box for brass moulding is shown in Fig. 56. A portion of the depth is parallel, the rest tapered. The sand cannot fall out in one direction, but it might in the other unless a little fillet is cast round the joint edges, as shown—as is done in middle-part flasks for iron moulders' use, and that holds the sand securely. An advancement on this is the doubly-bevelled

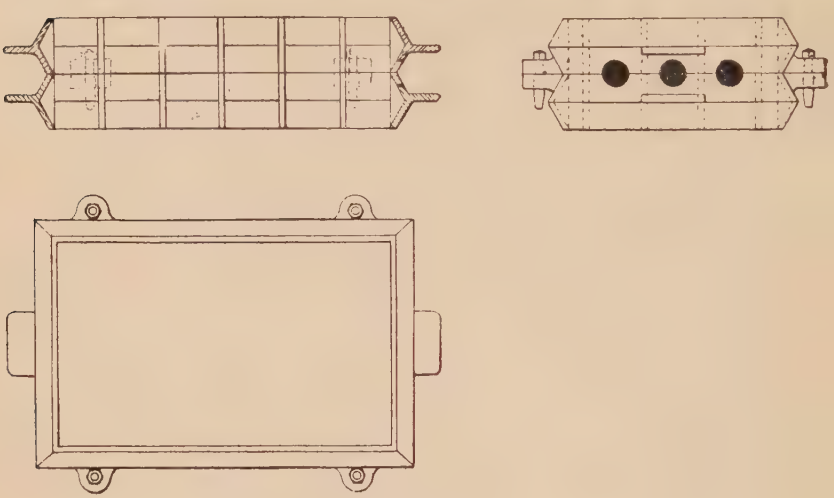


Fig. 57

box in Fig. 57. This effectually confines the sand in both directions, and when, as is often done, ribs are cast within the boxes —shown in the figure—the security is still greater. On the whole, it is the best flask for the brass moulder. The latest developments in moulding boxes are the snap flasks, which are hinged and fastened at cross corners. Hinged flasks not of the snap type are preferred by some rather than those with pins. Figs. 58 and 59 show one made in iron, A, A being the hinges, and B the catch. The vee fitting of the hinges prevents side play at one end, and the catch prevents it at the other.

Box Pins.—The pins of a moulding box appear very small details. Yet some amount of ingenuity has been manifested in

their design. Speaking generally, they are fitted into holes drilled in their lugs, but sometimes they are cast with their lugs, Fig. 55. The objection to this practice is that their accuracy cannot be depended upon as when they fit into drilled holes, and they are more liable to become accidentally fractured. When pins are fitted they should be turned with a shoulder, Fig. 57, to fit in and rest upon the lug, and be secured by means of a nut under the lug. The end of the pin that enters the drilled hole in the corresponding lug is well rounded, and frequently the pin is tapered away as

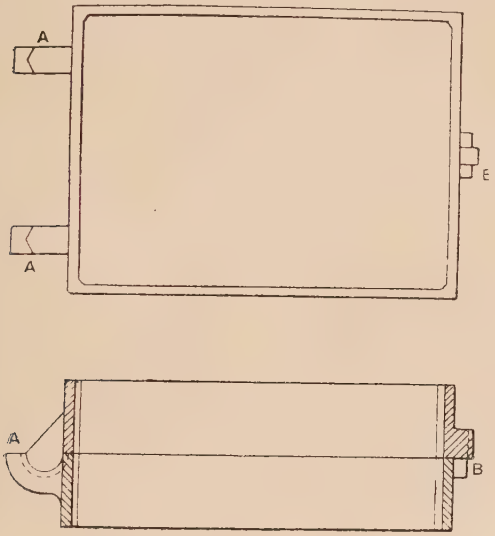


FIG. 58

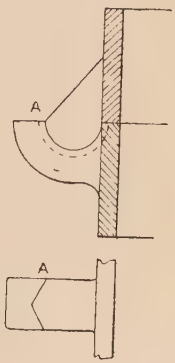


FIG. 59

well, leaving only that portion parallel which makes an actual fit with the drilled hole in the lug.

Handles.—Small boxes are not always fitted with handles for lifting them by, the moulder grasping them by the outside. Handles are desirable in all but the smallest, as the boxes are then less liable to slip out of the hands. Frequently long flat lugs are cast on, as in Fig. 57, giving rather less trouble in making than the wrought iron handles in Fig. 56, cast in, do. These must have prints on the pattern of corresponding outline, and the metal should be thickened up around them where they enter the cast iron. But they are the neatest and best for handling boxes with.

Wooden Boxes.—Boxes made of wood are not used so much as they formerly were. There is not much to be said in their favour beyond that of cheapness. They lack rigidity, and unless made very stiff and carefully used they are liable to wind and give trouble in damaged moulds. They become burnt in course of time by metal running over them. But in countries where timber is cheap and iron dear they fill a useful place. As these considerations do not exist in England, it is hardly worth while retaining wooden flasks for small brasswork. Those of iron can be bought cheaply, and in all sizes, both square and oblong, and of different depths. When flasks are made of wood the lugs are

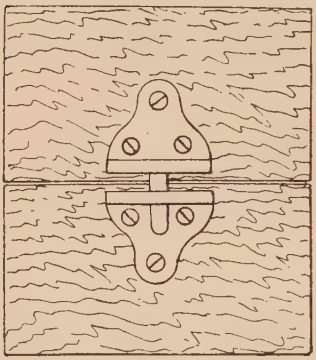


FIG. 60

FIG. 61

FIG. 62

FIG. 63

attached in various ways, Figs. 60 and 61 being common, and the best. Fig. 62 is an old device, the pin and plate fitting in the joint of the flask. Fig. 63 is also an old one, and objectionable, because it is not strong enough to resist an accidental blow upon the pin. Figs. 64 and 65 show a pin, in which the guide A can be shifted to adapt itself to wear, or shrinkage of timber, making the pin a fit under any circumstances.

Box Clamps.—Finished moulds when poured on end are secured with screw clamps, Fig. 66, that embrace the boards on the backs of the box parts. They are made of wood, hickory being preferred. The screws range from 1in. to $1\frac{1}{2}$in. diameter in different sizes, and the nuts are of fair length to ensure durability. Clamps of iron are also used.

Many classes of work necessitate the making of irregularly-

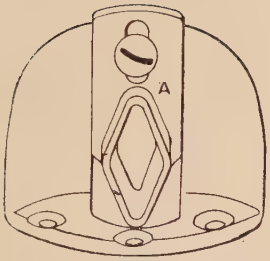


FIG. 64

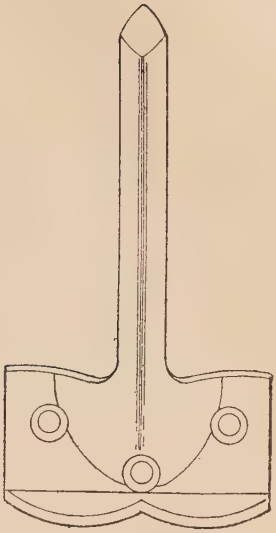


FIG. 65

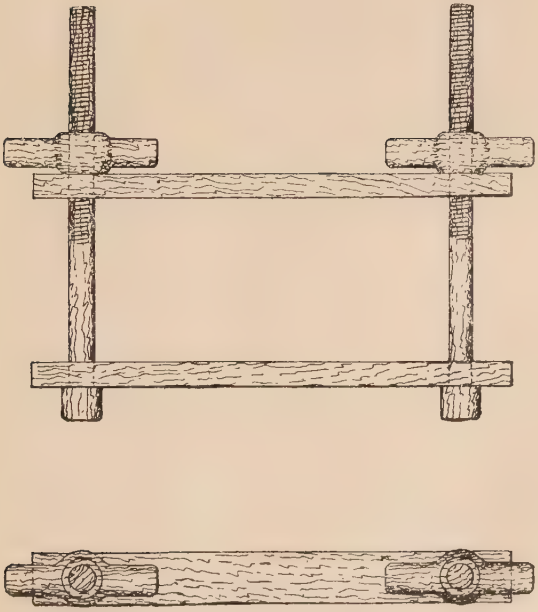


FIG. 66

shaped joints. These are generally made wholly in the sand, seldom in the flask. But there are cases in which a large number of castings are wanted, when it becomes desirable to make the joint edges of the boxes follow those of the pattern and casting. These have to be made specially for their own jobs, and are unsuitable for any others.

Much of the economy of brass moulding consists in putting as many patterns as possible in a single flask. To take a small flask and put one small pattern into it would be far too wasteful of energy. A number of small patterns are taken, therefore, and grouped in a relatively large flask, and this is often the only economy which can be obtained. An order from a firm of engineers may consist of a hundredweight or of several hundredweights of castings, from a dozen or a score of different patterns of various shapes and dimensions, which, along with other orders, are distributed to the men and boys in the shops according to their special qualifications. Boxes and follow-boards of suitable sizes are taken, and patterns arranged upon them in a manner most suitable for economy in ramming, and with due regard to the best method of pouring. Brass moulders become very adept in so arranging work as to leave but the minimum quantity of sand necessary for security between the nearest points of contiguous patterns. Even when a box will only take a single pattern of large size, smaller ones will be brought in to occupy otherwise blank spaces, runners passing from one mould to the other, and then the moulding of these will cost nothing, or next to nothing.

CHAPTER IV

JOINTS

Much of the economy which is effected in the brass foundry is dependent upon the methods adopted for making the joints of moulds. The smaller and more numerous the patterns, and the greater the volume of repeat work, the more valuable are the economies which can be effected in this way. This subject, therefore, will be considered in the present chapter.

Fig. 67

Joint Boards.—Joints are of two kinds, those which are flat, and those which are of irregular contour. Flat joints are made most quickly by employing a board, rather than by bedding patterns in, and sleeking the joints by hand, as in the more common practice of the iron moulder, and frequently, too, that of the brass founder. A large quantity of boards (Fig. 67) must therefore be kept in stock to suit moulding boxes of different sizes, and all patterns that have a flat on one face which can correspond with the joint of the mould should be laid upon these boards, and rammed thus in preference to bedding them into a box.

These boards are also used for the opposite outside faces of

the boxes for the purpose of confining the sand. They may be kept from curving by battens, though the better practice is to tongue cleats in the ends in the manner shown, in which case both faces are available for service. They are more readily weighted, also, if the pouring is done flatwise on the ground; if poured on end and the wood clamping screws are used, there is nothing to interfere with the latter. Often when pouring moulds flatwise the boards are dispensed with, and ordinary weights used, laid directly on the sand. In very light moulds weights may be dispensed with, the foot of the moulder keeping the cope down while pouring is done.

There are several ways of making the flat joints. In moulding some of the plainest work the bottom flask is laid with its back upon its moulding board, then rammed with sand, and its joint face scraped off and sleeked ready to receive the pattern or patterns. These are simply laid on in their positions, the top box placed over and rammed, its back board put on, the box parted, the patterns withdrawn and the gates cut. This method is only suitable for a simple class of work which is flat on one face. The box may alternatively be rammed from the back, as is most often done, the joint face being laid downwards on a board. The advantage of this method is that facing sand can be sieved to an equal thickness over the face of the board, and the remainder of the box filled with common sand. This is the general method of ramming a plain mould on a follow-board. The bottom half of the box is thus rammed, then turned over and the board removed. The top half of the box is next placed in position on the bottom half, the positions of the two being mutually located by the pins and holes in the lugs; and the top is then rammed over the remaining portions of the pattern. The boxes are now parted, the runners cut, the mould dusted with peameal or plumbago, and closed ready for pouring.

The waste of time involved in the adoption of this method may be, and often is, considerable, being very much dependent on the shape of the pattern. If this is of such a form that nothing but a level joint is required, then there is little loss. But when irregularly-shaped sand joints have to be made by hand for every pattern, and repeated for each mould, the loss of time is considerable.

Among the numerous shapes which occur, that in which a flat joint is made between top and bottom halves of the mould is the most common. In many instances this joint coincides with the centre plane of both the pattern and the casting. When, therefore, a few castings only are wanted, it is better to joint the pattern than to make it solid, because when jointed thus, the half pattern can be laid by its joint face directly on the follow-board. When the pattern is not jointed, the plain board cannot be used, but the pattern has to be bedded in a false mould until its joint plane corresponds with the plane of the box joint, and this work, so far as the actual complete mould is concerned, is thrown away, the sand in the false one being thrown out after it has served its purpose.

Non-plane Joints.—But there are numerous castings that cannot be treated in so simple a manner as this, even though they possess

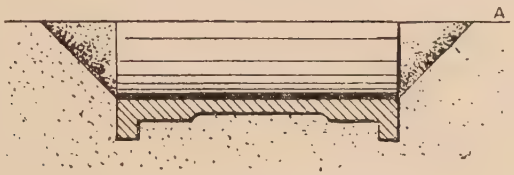


Fig. 68

flat faces which come in the mould joint. Take the common brass half-bearing, as typical of hundreds of other examples, in which the joint departs from the plane face to follow the outline of the bearing. It is clear that in such a case, though the joint face of the brass is laid upon the joint of the board, the joint must be continued round the curve of the bearing, and in order to permit of a parting, and of a lift without fracture, it must be sloped away. Let us note how this can be done.

Without employing a board, the brass is first bedded in a false mould, its bearing side upwards (Fig. 68), and rammed loosely in a position that will bring its joint face level with the joint A of the moulding box. Then the concavity of the bearing is cleared of sand, and a sloping sand joint made therefrom to the box joint A, at which stage the figure represents it. Parting sand is strewn over it and it is rammed. Then the flasks are turned

over, the false mould thrown away, and the top laid on in its place and rammed in the usual manner.

But when the brass is laid upon a board, joint face to joint face, it is bedded on a handful or two of sand which fills up the concavity and extends outside away from the ends. These ends are sleeked down, as shown in Fig. 69, in section, and in Figs. 70 to 72, to form the joint upon which the cope is rammed.

When a fair number of similar brasses is wanted, the trouble of sleeking every individual joint can be saved by using a convex block of wood cut to the same shape as a sleeked joint would be. Several of these can be stocked to suit brasses of different

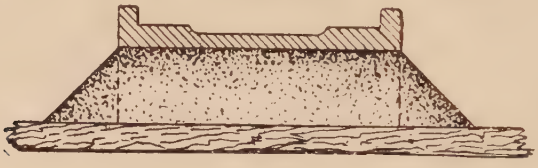


Fig. 69

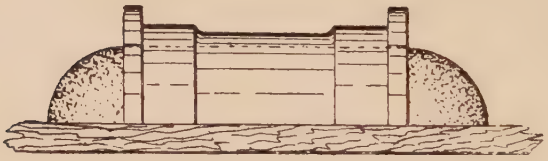


Fig. 70

bores, but since brasses vary so much in length it is impossible to stock all sizes. As, however, the exact finish of the sloping ends of the joint is not important, a difference of, say, 1in. in length is of little consequence.

Irregular Joints.—The joint for the brass bearing, though curved, is of a symmetrical character. But there is much work which has to be jointed in a more or less irregular fashion, up and down in various planes and slopes, which jointing occupies a considerable time. For this kind of work the "odd-side" method of moulding is most advantageous, being under some circumstances, at least, preferable to plate moulding. It is adapted to the requirements of jobbing and general shops as well as to those dealing with repeat work. Patterns can be grouped in such a way

that those for the first kind of work named may be moulded along with those of the second kind. Half a dozen patterns, say for repeat work, may be put in the same flask as single patterns, from which but a few castings are wanted to fulfil the order.

A greater amount of time can be afforded for sleeking the joints on the odd side than it would pay to occupy on work moulded in the common way, in which the joint is destroyed after each time of moulding and casting. An odd side properly made, well

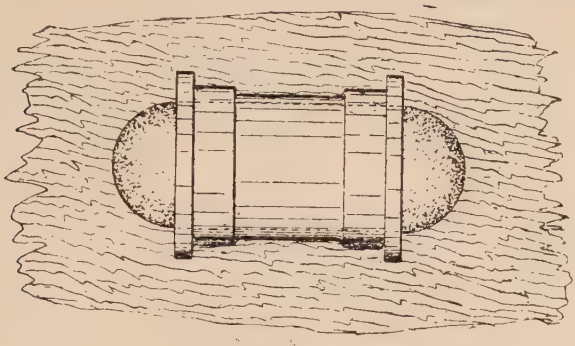


FIG. 71

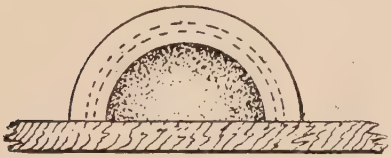


FIG. 72

rammed, and jointed in the way to deliver best, will stand the ramming of several dozens of bottom parts on it without suffering any serious damage. And the ingates and runners can be laid on, or cut in, as the case may be, once for all. In odd side, therefore, we have the perfection of irregular jointing. In this method of moulding, the positions of the patterns become changed from the odd side into the bottom part of the flask on the turning over of the latter. Then, after the top part is rammed and the patterns withdrawn, they are put back into the odd side for the ramming of the next mould.

The value of this method of moulding is seen in working from unjointed patterns, more especially with those the joint faces of

which are of irregular contours. Jointed patterns can be laid on a board or on a plate by their joint faces and so rammed; solid patterns in which the joints occur around the pattern bodies instead of on outer faces, cannot, except by the device of recessed joint boards or by making special plates.

Selected Examples.—We now consider the arrangements which are the most suitable for joints, meaning by that the broad considerations which should guide the moulder in making them.

In Fig. 73 the circular section A is one that delivers freely in top as well as bottom. The square section B would draw with

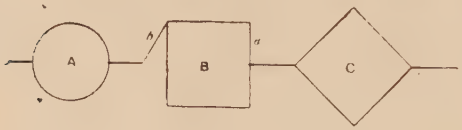


Fig. 73

Fig. 74

Fig. 75

Fig. 76

no taper in the bottom, but in the top the sand would break away if lifted from *a*, and the deeper the lift the more unfavourable would be the result. The best way, therefore, to arrange a square section is that shown at C, but frequently that cannot be done because other parts of the pattern would interfere with such an adjustment. Then a common practice is to make a sloping joint *b* on one square face of B, provided it is an unbroken face; and so, instead of having to lift, to let that portion of the pattern be drawn right from top to bottom. Sometimes a projecting portion which occurs on the face, and would, if left fast, interfere with the lift, can, if of small size, be left loose, and drawn inwards to

the mould subsequently. In other cases the lift has to be made some distance down at least, and the best job possible made of it by putting some amount of taper there.

An example of this kind is given in Fig. 74, which is a half brass of common type, moulded in various ways.. The best way to make it is with the bearing part downwards, a method which is not practicable when the metal is undercut as shown at *a, a* in Fig. 74. If the metal is brought up straight (Fig. 75), as in many brasses of small dimensions, it is easily moulded thus. But one of two things must follow: the facings *a, a* (Figs. 75 and 76)

FIG. 77

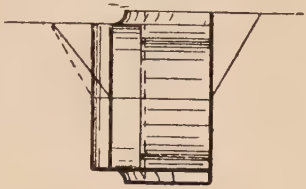


FIG. 78

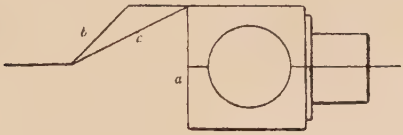


FIG. 79

must be left loose—which is seldom done—or else sloping joints must be made so that the sand can be lifted away from the vertical faces in the manner shown in Fig. 76.

When such a pattern is made to mould on its side, it is either jointed entirely along the middle—which involves a vertical lift of half the width, mostly of vertical faces, back and front (Fig. 77)—or sloping joints are brought down from the top face to the curved ends, half of which are therefore lifted in the top, leaving the whole of the back and front faces to deliver by the drawing of the pattern from the bottom, as in Fig. 78.

In Fig. 79 we have an example of a combination of circular with square portions. The circular parts are jointed down to the centre, but the smooth, square face *a* is formed by a vertical lift of the pattern, the horizontal joint being merged in that at *b*, or alternatively at *c*.

Fig. 80 represents a blank for a wormwheel. The usual method is to mould such work with a middle part, the joints of which come along the planes *a*, *a*. In brasswork few middle parts are used, and the result desired is attained by making a ring of sand A instead, carried on an iron ring, and having bevelled joints meeting the joint of both top and bottom parts, *b* being the joint of the latter.

Glands and work of that class can be moulded by jointing through the axial centre, in which case top and bottom parts of the mould are identical. An objection to this method is that the vertical faces of the flange and of the pattern ends are liable to fracture the top sand, unless they are given some taper. If moulded with the flange flatwise, as in Fig. 81, this difficulty is got over. The proper way to joint then is along the plane that lies flush

FIG. 80

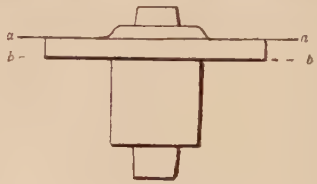


FIG. 81

with the top face of the flange *a*—*a*, and not along the bottom face *b*—*b*, as the latter would involve lifting the square edge of the flange in the top.

The angles, therefore, of mould joints vary anywhere from horizontal to perpendicular. A vertical lift is always to be avoided whenever practicable, though in some few sections of some patterns it is unavoidable. But as a general rule the vertical part should be brought into the bottom part of the mould, which will often involve another joint for parting, but one that may be formed with a steep slope. A careful man can often lift a vertical joint, provided it is shallow, with little or no fracture of the sand. When a little upward taper can be imparted, then the conditions are more favourable. In joints of this kind machine moulding compares favourably with hand lifts, because there is no unsteadiness in the machine lift, which is not always true of the moulder's hands. When a pattern parts, and the top portion comes up with the top, to be taken out subsequently, there is no advantage in

avoiding the perpendicular joints, because it is just as easy to withdraw vertical faces from the top—turned over—as it is to lift them out of the bottom.

In reference to the amount of slope which should be given to the sand joints, it is clear that a good, or a broken parting depends very much on the way in which these joints have been made and sleeked. An unwritten rule is that as much slope should be given to them as the job will stand. Like the taper in a print, it is better to give plenty than not enough, only the rule applies more forcibly to mould joints than to prints. First, because prints are generally drawn, but the top box is lifted off joints; second, because prints are of wood or metal, and the sand has little affinity for them, while joint faces are of sand, and sand has to be lifted from them, and the affinity between the two is likely to cause some coherence in places. It would invariably do so but for the loose dry film of parting sand which separates the two faces otherwise in contact.

Runners.—The proper arrangement of runners is a matter that calls for much judgment. Points which have to be considered are: The equal filling of every part of the mould, the remoter as well as the nearer, with sufficient rapidity; the exclusion of air; provision for the feeding, if any is done; the causes that produce sound, solid castings, or the reverse, etc. We find in practice, therefore, as much variation in methods as exists in iron founding, such as pouring at the top, at the bottom, and at the sides; the use of skimming gates and of risers; the practice of feeding, of casting vertically, horizontally, and on a slope; using hot and dull metal, and much else.

The terms runners, ingates, gates, or gits are used rather loosely. As a rule, there is seldom any distinction made between the ingate (which, in strictness, is the passage into which the metal is poured from the crucible) and the runner (or that through which it passes thence into the mould). Runners, gates and gits are the commonest terms used to denote both entry passages and the conducting channels alike. The actual entry is the head, runner head, or git head. But it will be well to understand the term ingate or gate as distinct from the runner or secondary channel. The term sprue is an Americanism, meaning the same as ingate, or it may denote also the metal in the head of the runner after casting.

Metal is poured into gates of various sizes and patterns, variously arranged. Uniform arrangements would not produce equally satisfactory results with different classes of work. Except for fairly heavy castings, sprays of runners, such as those which are used in light, thin iron castings, are not suitable for brass. Heavy castings are often poured at two places. There are usually three holes at one end of a standard flask for pouring. All three can thus be utilised for the work in the box, or one or two only. If a central ingate or ridge with sprays is used, each spray going to a separate casting, only one hole will be wanted. Or three distinct moulds or groups can be poured, each from its own runner, one after the other, precisely as though the moulds were made in separate flasks.

When arranging runners, a general rule is that the farthest mould, or the lightest part of the mould, shall be filled before the metal begins to set. It is desirable, therefore, to arrange castings of approximately the same mass in a flask. But very often lighter or heavier ones must be included. This need give little trouble if the runners are sized properly and their locations suitably arranged. Light castings can receive their metal through heavier ones, but not through other light ones, in the passage through which the metal would be likely to congeal. Sometimes it is better to bring the metal through thin castings into heavier ones, or through the thinner sections of heavy ones first, rather than directly into thicker portions, and for the same reasons to ensure that the metal runs up and fills the thin portions, which it might not do if brought into the heavier parts first. But where such risk does not occur, it is better, as a rule, to pour into the heavier metal where the greatest shrinkage occurs. Large runners are then available, and these may serve as feeder heads by the addition of fresh hot metal, as that in the mould shrinks and sinks in the head. Feeding in a thin portion would have no effect on a heavy mass adjacent. Judgment must be exercised in all these details, because brass sets quickly; and it would often happen that the metal would congeal in a light section before the required quantity could be passed into the heavy portion of the mould. There is therefore a limit to disproportion and to relative cubic contents and to the distance through which metal will travel in the narrow channels.

Another good rule is to avoid, whenever possible, bringing metal in against faces that have to be tooled, or where it will be beating directly against cores. The metal next to an ingate is the most porous in a casting, which explains why it is desirable, when the choice is possible, to bring it in away from any parts that have to be bright, or where special soundness is required. If this cannot be done, then casting quickly under a moderate head, followed in some cases by feeding, after proper mixing and skimming, are the courses to be adopted. It is better also to bring in metal in a line of least resistance—*i.e.*, to let it run in without abrupt change of angle, and to travel along as free a course as possible without cutting up sand and dirt.

Since the flat, very thin runners used in light iron castings cannot be used in brass work, because the metal would solidify too quickly in them, those for brassfounders are generally round,

FIG. 82

FIG. 83

square, or oblong in section (Fig. 82), and large in proportion to their castings. The ends next the casting are also commonly formed with a slight radius rubbed in the mould, so that if knocked off while red hot they do not break off inwards into the casting. Fig. 83 shows two modifications of the square runner most frequently used, A being contained only in one half flask, B in both halves.

In saying that round and square runners are employed rather than thin ones, this of course has reference only to those that are very thin. There is a great deal of thin work that must be poured with runners of oblong section, like that to the right of Fig. 82, because to use round or square ones of large area on the edges would be impossible, and to employ them on the flat faces of the castings would cause a draw, or sponginess in the vicinity, and probably produce a concavity on knocking off the runner. The important point is to make runners for brass larger in size than those for iron, and to give as much thickness as is practicable; and, as in iron but in a greater degree, diminution in thickness

must be compensated by increase in width and in number of runners, the object to be attained being to fill the mould completely before the metal begins to chill.

Pattern Runners.—A stock of standard runner pins is kept in the brass foundry. They may be of wood or iron in the larger sizes, or brass in the smaller, and of round, square, or oblong sections, advancing in sizes by $\frac{1}{8}$in., to suit the whole range of work. Runner pins are mostly made in wood—of soft pine generally, which answers very well, because they are easily renewed when worn, bruised, or burnt. Pattern sprays of runners on a central ingate are of little use for general work, though of value in a shop doing a fairly constant class of standard goods. A practice which is adopted, even though but a small number of similar pieces is required, is to cast patterns of ingate and runners,

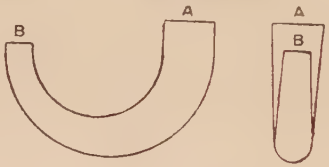


FIG. 84

formed by arranging the group of patterns in their most suitable locations in a temporary mould, and then cutting and sleeking the runner moulds, and pouring in a white metal alloy. This is put loosely into the mould containing the patterns for the work required, if these are of wood, but if they are of metal the runners can be attached thereto, either with solder, screws, or rivets. This saves the cutting of the runners each time of moulding. A useful shape of pattern runner is shown in Fig. 84. It is of circular section, and employed for pouring vertically. It is rammed in the mould, meeting the vertical pin at A, and in its passage conducts the metal round to the bottom end of the mould at B.

Vertical Pouring.—But only a moderate proportion of brass is cast vertically, contrasting strongly in this respect with the work of the iron foundry. It seems that pressure alone—which is so valuable an aid when sound cast iron is wanted—is not sufficient to ensure sound work in brass. Apparently it is better for this that an even and but moderate pressure should be exercised throughout the entire mould, in preference to an excess at the

bottom and comparatively little at the top. But whatever the correct explanation, it is certain that, as a general rule, better results are obtained in horizontal, or nearly horizontal, casting than in vertical. The writer has known heavy work, such as blanks for penstock screws, weighing from 3cwt. to 5cwt. each, large brass liners, the window and door frames of lighthouses cast flat and with perfect soundness, as evidenced by the fact that they were tooled everywhere without showing specks. Probably the explanation is to be found in the fact that the alloying elements in the brasses and gun metals separate out under pressure, and so prevent a homogeneous result. Casting work not very deep under a moderate head only is, however, not open to any objection, and is commonly practised.

In pouring brass an important point is that the runner be kept full of metal. This is generally accomplished when casting iron by having a pouring basin which is cupped or depressed in one locality below the level of the top of the ingate. The result is that the first lot poured sinks into the depression, filling it up with a body of liquid metal before any gets into the mould. There is reason for this in heavy work, because some little time is necessarily occupied in making final adjustments of the ladle just when commencing to pour, and if at the beginning drops of metal get into the mould before the principal volume, they may form cold shots. The first metal, therefore, is poured slowly, during which time careful adjustments are being effected, and the pouring into the actual mould takes place in a steady and rather rapid stream, which keeps the pouring basin full up and level until the mould itself is completely filled. During this time, if any scum passes the skimmer and falls into the basin, harm seldom results, because it is buoyed up on the metal in the basin, and there remains outside the mould.

This is very well in iron, but there are obvious objections to adopting a similar method in brass. One cannot spare a half-hundredweight or a hundredweight of metal for the basin of a brass casting, the metal for which has to be melted in crucibles, and the wastage of which is costly. But yet it is necessary to keep the ingate full during the time of pouring, for nearly the same reasons as in iron. There is no trouble in steadying a crucible held in a shank or in tongs, as there is in a heavy ladle

slung in a crane and tipped by worm gear. But there is the serious risk of scum and air getting into the mould. In order to prevent this, the ingates, though simply cupped in the head, are made of such a size that the metal will enter the mould sufficiently quick to fill it properly before the metal sets, yet not so quickly that it will rush in and leave none in the ingate. It is therefore a question of size of runner and ingate and rate of pouring. If the metal were to run in too quickly, though there

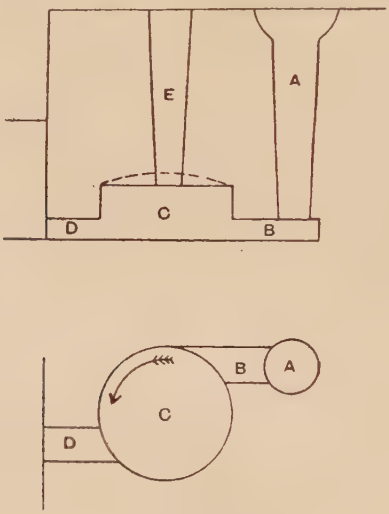


FIG. 85

would be no risk of its cooling too rapidly, any scum in the ingate would be sucked in and spoil the casting, and air would also enter and cause blowholes. These facts explain why, in fixing the proportion of ingates and runners to each other and to their castings, the moulder's judgment has to be exercised in every separate job, and experience of previous work is the only safe guide.

Skimming Gates.—Skimming gates are of equal value in brass moulding as in iron. The theory of the skimming gate is known to most, but it is well to explain it, since errors are made by moulders who fail to grasp the real principle, and so form gates which do not skim. The principle is this: that molten metal under the action of centrifugal force will fly to the outer part of a circle,

leaving the lighter dross near the centre. The skimming gate is so arranged that the whirling metal alone is sent into the mould, the dross remaining outside in the globe or disc.

The elements and details of such gates are shown in Figs. 85 to 88, in which A is the ingate, B the runner to the chamber C, D the runner into the mould, and E the riser up which the dross finds exit. The essential point is that the runner B shall come in at a tangent in order to impart the necessary whirl to the metal. If that is fulfilled, the arrangements may vary as in Figs. 85 to 88, which show different angles and right and left-handed gates.

The skimming chambers may be either discs, as shown, or globes. But a globular chamber is better than a disc, even though there is no difference in area, because the dirt is less likely to be

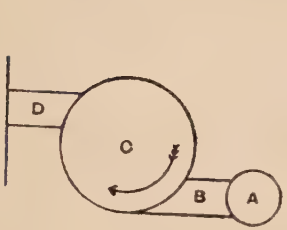


FIG. 86

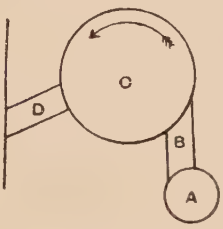


FIG. 87

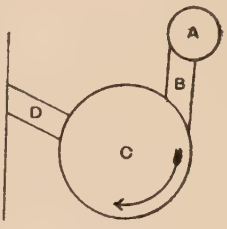


FIG. 88

arrested against the top of the chamber in the globe than in the disc. The latter can, however, be made with some convexity at the top, as shown dotted in Fig. 85, leaving the bottom flat, this being frequently done.

The reason why the skimming chamber is made so large in relation to the ingate and to the entering runner is to give time for the dirt to separate and accumulate in the riser. If the metal were run through a chamber of equal area with the runner, it is clear that there would be no delay in the transmission of the metal, and so all the dirt would go straight into the mould. There is probably no rule and no exact proportions necessary for skimming chambers. Experience settles these, and the drawings give proportions which the writer knows to accord with good practice. It might seem that the same end would be attained by dispensing with the circular chamber if the runner and riser were connected with a straight passage of large area. But though better than

nothing at all, it would not impart the necessary rotary movement to the metal, which is so important and vital an element in the separation of the light dross from the heavy metal. A detail which is conducive to the entry of clean metal into the mould is to have the runner large enough, but no larger than is necessary, for pouring hot and filling completely. The runner should be level with the bottom of the chamber (Fig. 85), where the heaviest metal is, and be oblong rather than square in section, the shallow part of the section lying in the vertical direction.

Brass moulders are now catered for so well in respect to skimming gates that it is not necessary to cut them in each mould. They are made in metal of different sizes, and right and left-handed.

CHAPTER V

JOINT BOARDS, ODD-SIDES AND PLATES

Alternatives in Joints.—Much variation exists in the methods of moulding adopted in the brass foundry. As illustrative of the ways in which a casting may be produced, take the common globe valve, Fig. 89, selected because it is so common an object, and

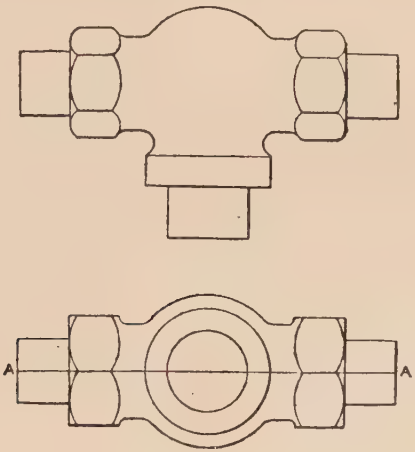


FIG. 89

because it is not complicated by double joints and middle parts, loose pieces, or other special details. The obvious way of making and moulding such a pattern is to joint it along the centre A—A as shown, and mould it by turning over—that is, by ramming each half in turn in the top and bottom boxes, the pattern halves being retained in their proper positions by means of dowels. That would be the method of the iron moulder, and in the case of special cocks and those of larger dimensions, seldom required, it would generally be adopted by the brass moulder. But for turning out

large quantities the dowelling is objectionable, and having to make the mould joint by hand is also undesirable.

In the next method, which is a point better, the dowelled pattern is still retained, but one-half of it is laid on a bottom board, Fig. 90, and thus rammed; the joint face is formed by the face of the board instead of by a trowel, and the necessity of first bedding in one-half the pattern, level with the joint face of the moulding box, as done in the first method, is avoided.

FIG. 90

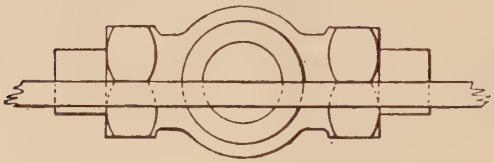


FIG. 91

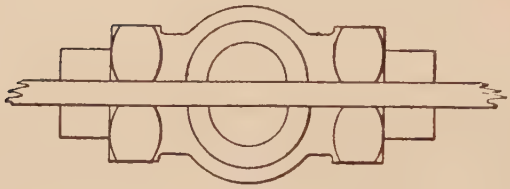


FIG. 92

The next better way, and one that is most commonly adopted, is to make the pattern without a joint, and to lay it in a recess cut in a board, Fig. 91, to a depth which just brings the centre plane of the pattern level with the face of the board. The bottom half of the moulding box is then set upon the board, and the upper half of the pattern rammed. Box, board and pattern are then turned over, the board removed, the other half-box put on, and rammed over that portion of the pattern which had previously gone below the joint face of the board.

Another method is to joint the pattern as in Fig. 89, and fasten each half on opposite sides of a single board (Fig. 92), to

which board the pins of the moulding boxes are carefully fitted, and then to ram each half-flask on its own side of the plate. Or two separate boards are employed, each having one-half the pattern fixed upon it, and each half-box being rammed on its own distinct plate. In both these cases very careful fitting of the pattern halves to the boards, and of these to the boxes, is important, in order to prevent the formation of lapping joints. On the same plates, also, the ingates and runners may be fitted.

Now, finally take similar boards, or take metal plates fitted with a single large pattern, or several small ones, and withdraw the boxes from the patterns by the aid of a machine, and we have the most economical method of moulding brass cocks. The machines may be operated by hand or by water, steam, or compressed air, marking then the highest economies of the present time. From this elementary object lesson we may now proceed to the details of arranging patterns for brass moulding.

When a number of castings are ordered, the quantity required generally determines the method of making them. Usually in such cases some system of plate moulding is adopted, to which the pattern parts have to conform. In standard work of medium and small size, wooden patterns and coreboxes are not so much used as those of metal. When wood is employed, the best, closest-grained mahogany is better than anything else, because when well seasoned it retains its shape best, and is less affected by the rammer and vent wire. Other woods are harder, but also more liable to warp. Pine, though used for large patterns, is too soft to stand much constant service in small ones. It is suitable to make patterns from which metal ones are to be cast.

Joint Boards.—We will now consider what aid can be rendered by bottom or joint boards in jobbing work. This is a stage in advance of the method of bedding-in recently described, a half-way stage between those and the method of moulding by special boards which can only be used for a special job or single set of work. There are numbers of patterns which are flat on the top face, numbers also which are jointed and dowelled in the centre or elsewhere. All these are adapted for economical moulding by the assistance of joint boards, in which case the work of bedding-in is saved.

The alternative to the joint board is to make a level joint in

sand in the box, which will ultimately be the top part or cope. This is just shovelled in and flat-rammed or trod in with the feet, strickled off level with the joint face, and the patterns or parts of patterns are arranged upon this to be rammed.

But even this work should be avoided by the use of joint boards, of which a very large stock ought to be kept in any foundry. Every size of box should have its suitable board, or

FIG. 93

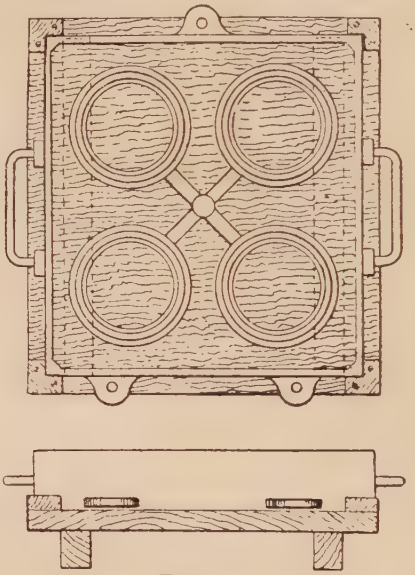


FIG. 94

boards, stored ready for use, and kept in trim from time to time by the patternmaker or carpenter. Such boards may be constructed in various ways. Generally those of small and medium size are made of plain board—red deal or oak, with cleats tongued at the ends (refer to Fig. 67), and having both faces planed truly.

Another plan is to build up the board in two thicknesses of narrow strips, without cleats. The strips run either at right angles with each other, or diagonally, and are separated with open joints (*see* Fig. 99). Such boards maintain their truth better than the others. They may be bound down the edges with strips of hoop iron.

A third type used for large boxes is made of narrow strips with

open joints, retained in place with battens or cleats on one side. One side only of the board can then be used, but that is just as well as having two sides in the heavier class of work for which they do service. The cleats can soon be made to bed on the sand of the floor, and the board readily taken out of winding for the reception of the flask. Examples of these boards are seen in Figs. 94 and 101.

In making use of such boards the flask need only be laid upon the plain face, without any setting by means of its pins. To set it by pins generally means either a slop fit or a tight fit—that is, no fit at all in the majority of boxes. This method is therefore suitable for standard work with box pins exactly fitting holes in boards. A better method is to set the box by corner pieces, as in Fig. 94.

FIG. 95

FIG. 96

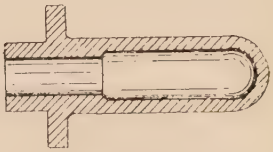


FIG. 97

When selecting patterns to lay on a joint board, it is well to have some degree of uniformity in their depths and general proportions. The figures illustrate good arrangements.

Pattern Arrangements.—Fig. 93 shows a brass facing such as is used for the plugs of sluice cocks. These facings are cast first and turned, and the iron plugs cast around them, holding by the ring A, which is undercut by the turner on inner and outer edges. Such rings are wanted in considerably quantities, but in different sizes for different valves. They can be moulded economically by the method shown in Fig. 94. A plain bottom board with corner pieces receives the box part, and the rings are laid within it to give suitable amounts of sand between each other and the box sides. A git pin or ingate pin is stood in the centre and a pattern spray of runners. Or the runners can be cut in the mould. Fig. 94 shows the pattern, the pin, and the runner pattern arranged on the bottom board, enclosed by the bottom box, as they appear when the moulder is about to commence ramming. It is not necessary to carry the description of this mould further.

Figs. 95 and 96 show two pieces of pump work, neither of which is flat on the top face. One is recessed, giving a disc or plate; the other is recessed also, but over the edges of arms. But either job can be arranged as in Fig. 94, because the outer edges make a flat joint with the board, and the recessed portions at the back can be dealt with after the bottom box is rammed and turned over in readiness for ramming the top box.

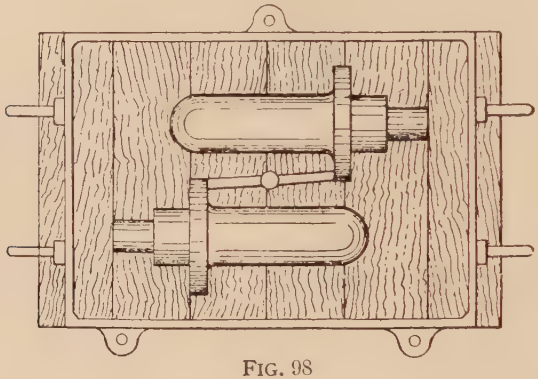


FIG. 98

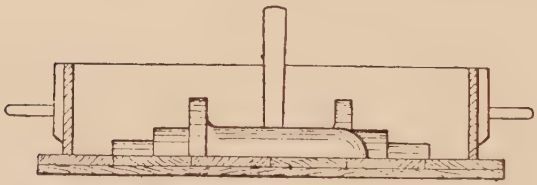


FIG. 99

An example of a different kind is the valve-rod guide (Fig. 97) used on some engines. This is a pattern which is never wanted in large numbers, and it is generally jointed and dowelled, and the shape of the core marked in the joint face. Large sizes may be arranged two in a box, as in Figs. 98 and 99; smaller ones four in a box, as in Fig. 100. The joint face which contains the dowel holes is laid upon the bottom board. In Fig. 100 the patterns are shown united, two in one, connected with a print common to both. One core is then used for both. The reason for this is seen on looking at Fig. 97. The core can be supported in a print at one end only, the other end being a dumb one.

Hence a very long print must be used, sufficient to counterbalance the core, or a couple or three brass chaplets must maintain the core central at the dumb end; or the double core must be carried in a central print impression, as in Fig. 100.

Two half patterns of cock bodies are shown in Fig. 101 on the joint board in readiness for ramming. These, however, do not fill up the box which happens to be available, and so two screwing flanges are placed at the flanks. Then as there are four corners unoccupied, two flanged nuts and two plain bushes are found and placed in. The pouring is done from one ingate at A, pouring with two narrow but deep runners into the flanges adjacent, the

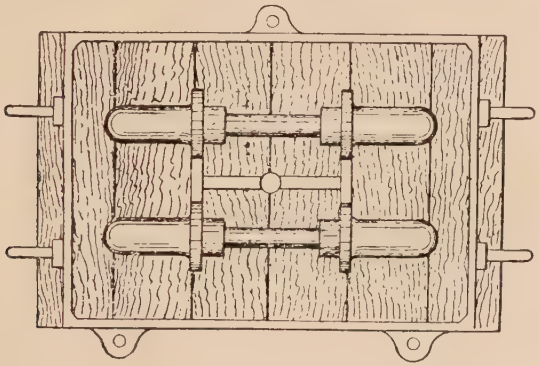


FIG. 100

metal then passing through the valve bodies into the flange on the far side, and into the nuts and bushes. The metal will retain its fluidity sufficiently long to run a good distance when the castings are of fair thickness, as these bodies are.

Recessed Boards.—We now go a stage further and take the joint board that is specially prepared for one set of work only, and which cannot be used for any other—that type of board illustrated in the figures which is recessed to receive certain standard patterns. These patterns may be all alike, or of a miscellaneous character. The most suitable arrangements are those which harmonise best with the work of a given shop. Speaking generally, it is better to fit a number of similar patterns on one board. But unless the sets of similar work done are turned out in large quantities, economy will be better studied by taking several separate articles from different sets, and fitting them into the

boards. In some cases a complete set of work, comprising the different patterns in a set, can be put on one board, in others two or more sets. It is all a case of convenience and economy, and no exact rule can therefore be laid down.

The case for recessing boards is when patterns have no flat faces and are also unjointed. Using these boards, unjointed patterns can be moulded without the trouble of making and

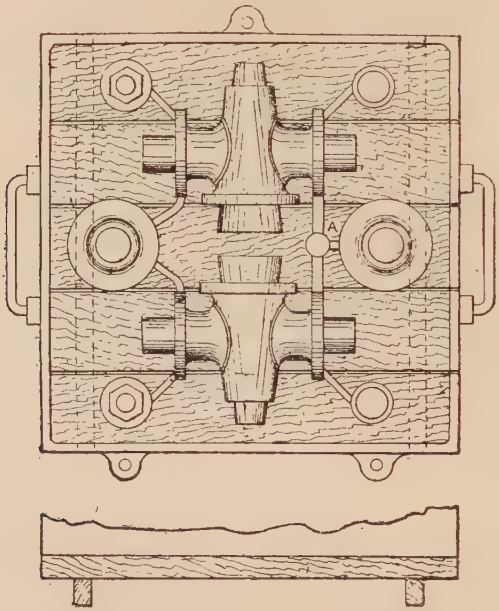


FIG. 101

sleeking the joint with a trowel. But this applies to very large numbers, especially in the smaller sizes, in which it is injudicious to use jointed patterns, since those which are jointed and dowelled inevitably become loose in time, and produce some amount of overlapping of edges. Either wood or metal patterns also can be fitted in this way, or both kinds may be set adjacent in the same board. And further, if any irregular joints are wanted against some portions of a pattern, they can be made by fitting and nailing extra pieces of wood of the proper shapes on the face of the board against their patterns.

These patterns—very commonly of metal or else of hard and

close-grained wood—are let into the joint boards exactly level with the joint line at which the top and bottom flasks have to be parted. Such boards have been used to a considerable extent in brass foundries, and when they are displaced it is usually by some system of plate moulding. But in shops destitute of machines it is a very suitable method, and such boards, if carefully made and used, will last for many years. Once prepared, all the work of arranging standard patterns on plain boards at each time of moulding is saved, and also the time of making the runners can be saved by placing them on the boards.

Various arrangements of patterns in joint boards are shown in the illustrations. In each case the face of the board is seen as it appears previous to ramming, the patterns being all in place ready to receive the bottom box. Pattern runners are seen attached to one of the boards, but they are sometimes left to be cut in the sand. The bottom box is rammed over the patterns, and the board, box and patterns are turned over bodily. The board is then removed, leaving the patterns behind, standing up from the joint face of the bottom box. Any loose sand is then blown away with the bellows, the top box put on, parting sand strewn, and the ramming proceeds in the ordinary way, after which the box parts are separated and the patterns withdrawn, and the coring-up done.

For the convenience of description we may divide these boards into two classes: those in which patterns so shallow are used that the boards are not cut right through, but only partly recessed for their reception; and those in which the depth of the patterns involves cutting the recesses right through. Large numbers of patterns come under both heads, including those of similar shapes, but of different dimensions.

In the first class, since the board is not pierced through, the grain can be continuous, as in Figs 102 to 104. In the second case, shown in succeeding illustrations, the recessing severs the continuity, and therefore the board must be built of crossing pieces. In the first the board can be laid flat on a bench; in the second it must be carried on battens, as in Figs. 105 to 107, or else on the other half of the box, as in Fig. 112.

Figs. 102 to 104 give illustrations of similar patterns, being union nozzles for hose pipe. The board is made of rather narrow

strips to lessen shrinkage, and these are retained with dowels in the joints to maintain the faces flush, and with cleats tongued at the ends. The two views, Figs. 103 and 104, give sections through board and patterns in the directions indicated.

A board made thus in single strips and then recessed through,

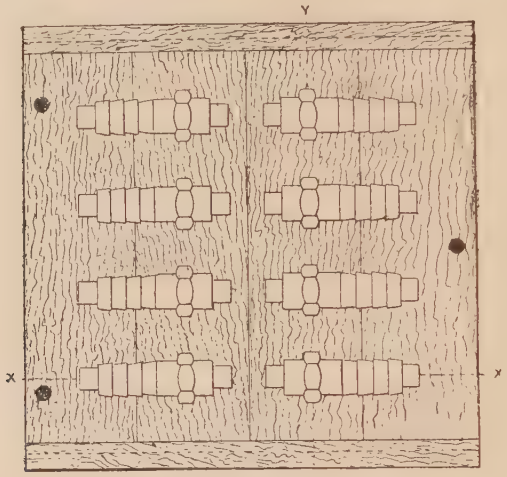


FIG. 102

Section at X X

FIG. 103

Section at Y. Y

FIG. 104

as in Figs. 105 to 107, would have its continuity severed, and therefore this is made with strips crossing each other at right angles—as shown in the illustration—or diagonally. They should be glued on the faces, but not on the edges, and after the recesses are cut, the broad flat areas are nailed with wire nails driven in from the bottom side of the board, which is never used. Cleats may or may not be fastened at the ends, or stout hoop iron. Holes are drilled for the pins of the moulding boxes. The

patterns in Figs. 105 to 107 are those of union coupling nuts, and Figs. 106 and 107 give views through the sections of the board and patterns. As these patterns come through, the board

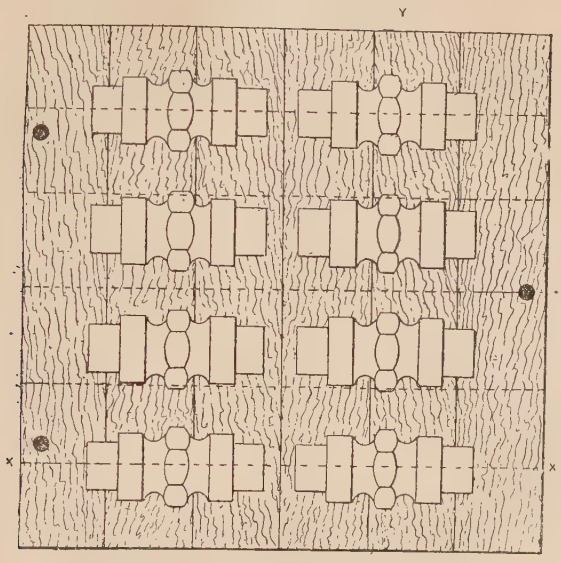
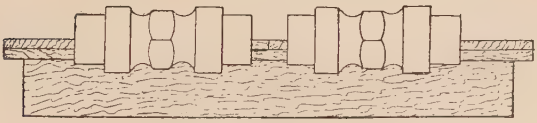


FIG. 105



Section at X, X

FIG. 106

Section at Y, Y

FIG. 107

must either be carried on battens or strips, as shown, or it must be laid on the joint face of a box.

Figs. 108 to 110 illustrate a similar case of cutting through the board, and it also shows the runner patterns attached to the board. Fig. 111 is a case of putting various classes of patterns

into one board—four globe valves, two check valves, two plugs, and one union piece. Fig. 112 gives a longitudinal section through the board, which is seen lying on the box part, and which will presently be the top. In these drawings it is not necessary to mention the prints and other features of the patterns, as these will be understood by those interested in the subject. Neither is it necessary to show later stages of the moulding.

Some considerable time is spent by the pattern-maker in fitting the patterns into the board to the exact depth required to bring the joint right. But every portion need not be made to fit in

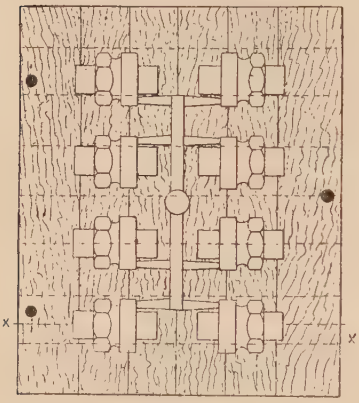
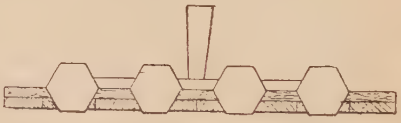


FIG. 108

Section at X X

FIG. 109



Section at Y, Y

FIG. 110

exactly. For example, in most of the figures, if the end prints are fitted closely, that will prevent the patterns from shifting, and elsewhere the board may be chamfered away from the joint edge, instead of being cut to semi-circular sections.

Boards must be stiff enough to resist ramming, and the truth of the faces preserved as long as possible. They are liable to become bruised by the rammer, marked with the vent wire, and burnt and warped if allowed to lie about anyhow. A few coats of paint or varnish are preservatives. But in any case the boards should be kept in racks, preferably on edge, when not in service. Red deal is a good material to use, being moderately hard and not liable to warp.

Odd-Sides.—Odd-side work fills a large place in brass foundries, and is scarcely second to plate moulding in its economical

importance. The term expresses the exact device employed—namely, a mould side, or a part that forms no portion of the finished mould, but which is laid aside when its special and temporary function has been fulfilled. An odd-side takes the place

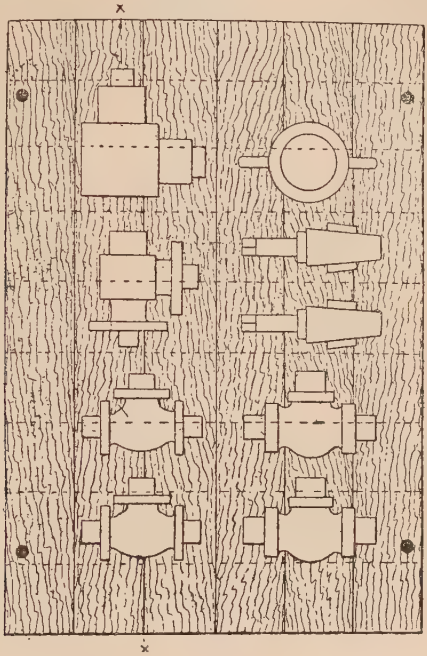
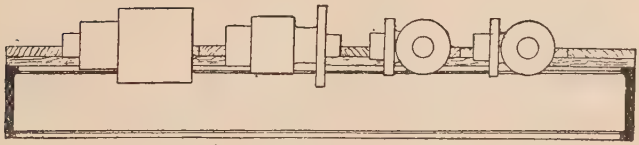


FIG. 111



Section at X. X

FIG. 112

of the first portion of an ordinary mould that is made by rolling over. Though recapitulating a previous explanation, this process may be re-stated.

In ordinary turning over, the pattern is bedded-in a false mould —usually in the box part which is to be the top portion subsequently,—the object of this rough and temporary bedding-in being simply to set the patterns in their proper positions and to form a

joint face. This face may be level, or irregular. On it the actual moulding is begun by placing the bottom part of the moulding box over it, and ramming that over the pattern. Then the mould is turned over, and the box in which the patterns are temporarily arranged is taken off, leaving them in the properly-rammed bottom part, partly embedded therein, and partly standing up from the joint face. Any loose sand is now blown away, parting sand is strewn over, and the box part just removed is knocked out, cleared of its loose sand, replaced on top, and rammed properly to form the top part of the mould.

The trouble of setting a pattern thus in a temporary mould, and making and sleeking the joints, is saved by the use of the bottom boards previously described. But the utility of these does not go far enough, because many patterns are so shaped that they do not admit of flat dividing joint faces. When wooden boards are used for such, extra pieces are fitted on the board, or else recesses are cut in the board to form the sloping or irregular joint faces which are required. But it takes much longer to cut wood than to shape sand, and it is not practicable to effect ready alterations in timber; and so the odd-side comes in as the best solution of the economical production of that class of moulds in which the joint faces are not flat, but irregular. It takes the place of a false mould, such as is made by bedding-in the patterns and making the joints for ordinary moulding, only instead of the bedding-in and joint-making having to be done at each time of moulding, it is done once only for a large number of moulds, which may number scores or hundreds, according to the material of which the odd-side is made.

In this method the patterns are not divided, but are laid bodily in the odd-side in their impressions in it. Gates may be cut, or preferably their patterns laid on in place. The drag or bottom part of the box is then laid down upon it, and rammed and levelled on the back. It is then turned over and the odd-side removed, leaving the patterns standing upon the faces previously embedded in the odd-side, and with the joint faces, whether of plain or irregular outlines, ready to receive the cope or top box. This is now placed on and rammed and lifted. What is saved, therefore, is the bedding-in as often as the moulding is repeated, the making of the joint face, and the cutting of the runners. Also, in machines

fitted with a presser the ramming is lessened, since the sand is shovelled in, a board laid over it, and pressed down at once.

There are two general cases in which odd-side moulding is specially economical. One, that in which, though a level joint is used, it is yet divided into various sections by the pattern; the other, in which the joint is uneven—irregular,—being curved or sloping to follow the line of separation rendered necessary by the contour of the pattern.

An example of the first kind is seen in the handwheel mould, Fig. 113. The joint, though quite plain, has to be made around the rim inside and out, and in six arm spaces, by the trowel and

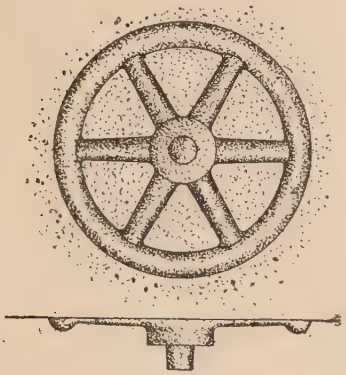


FIG. 113

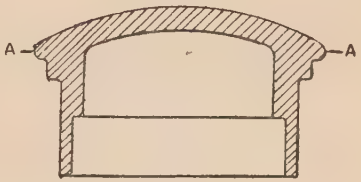


FIG. 114

flat end of the cleaner; and in ordinary moulding this has to be repeated for every wheel casting made. If the joint does not correspond with the central plane of rim and arms, some parts of the mould will be undercut and tear up. In a divided pattern, the pattern joint supplies the guide to the trowel, but in unjointed patterns the moulder has to trust to himself, though when several moulds are to be made a little strickle is often improvised. But having an odd-side the shape of which is seen in Fig. 113, the joint is made once for all for many scores of moulds, the pattern going back into it at each time of moulding. The joint-making in such a pattern occupies more time than it does in going round, say, a globe valve or a plain cylindrical pattern, and therefore the economy of the odd-side is correspondingly greater.

Now take the cap (Fig. 114) of a lock-up safety valve.

Although only a plain joint round the edges is wanted, yet the pattern has to be bedded-in to the joint edge A—A, and the time required for this is saved by an odd-side. The appearance of the latter would be either Fig. 115 or 116, depending on which part is to come in the top part.

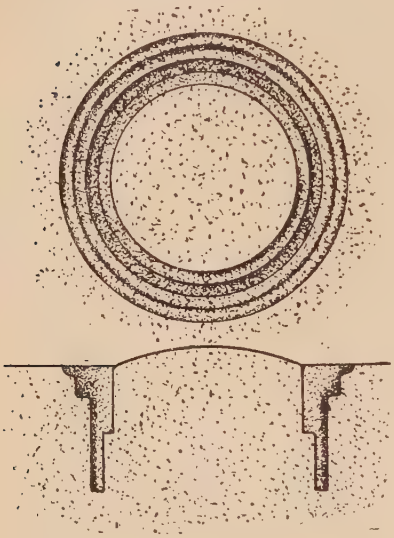


FIG. 115

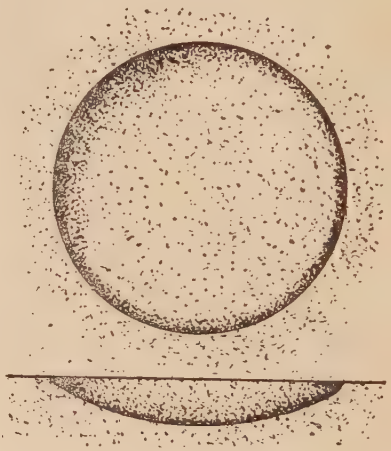


FIG. 116

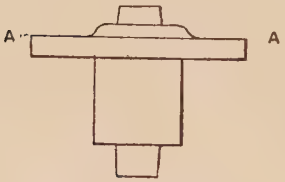


FIG. 117

FIG. 118

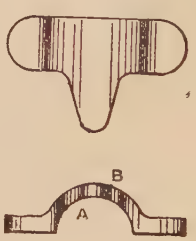


FIG. 119

Fig. 117 would nearly always be moulded as it stands—perpendicularly. The only preparation on this for an odd-side would be a recess to take the top facing boss and its print, as in Fig. 118, the mould joint coming along A—A in Fig. 117.

As examples of the second class, that including irregular joints, take first the clips for hose pipe in Fig. 119. Here a curved joint has to be made to follow either edge A or B—it is a matter of

no importance which—thence to slope away to the general plane of the joint of the moulding box. Such joints always take some considerable time to make. The appearance of the odd-side is either Fig. 120 or 121, according to which face is cast down.

Again, for the axle-box brass in Fig. 122, the odd-side would be like Fig. 123 or 124, the back of the brass being bedded-in in the first, and the face in the second.

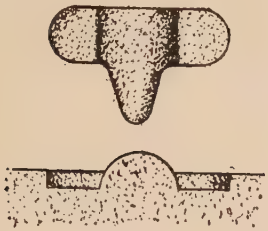


FIG. 120

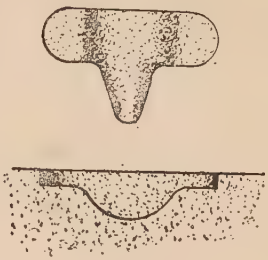


FIG. 121

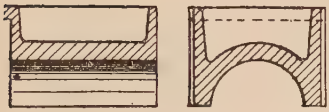


FIG. 122

FIG. 123

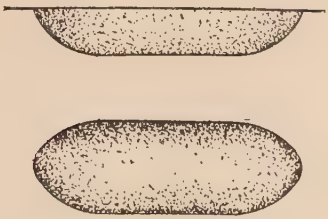


FIG. 124

Now when not one pattern merely, but half-a-dozen, or a dozen or more, whether alike or dissimilar, are put into a single box, the economy of the odd-side is manifold. There is a great deal of making up, cutting away, moulding, and sleeking in a box full of patterns, which when done once for all in the odd-side saves

that labour many scores of times over. And when ingate patterns are laid on or cut out in the odd-side, the repeated preparation of these is also saved for all the patterns in the box.

If the work already illustrated is now arranged in one box, then the appearance of the odd-side will be as in Fig. 125, and the same with the patterns in is seen in Fig. 126.

When an odd-side is prepared in sand, the latter is rammed very hard, and the patterns arranged, and the joints made with

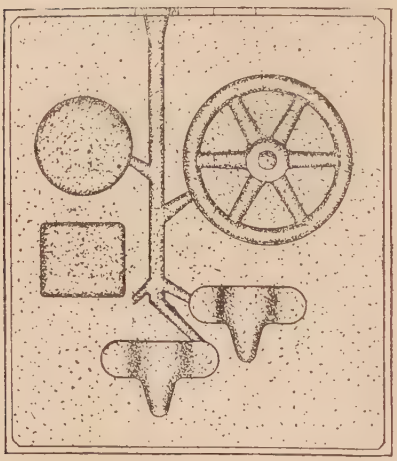


FIG. 125

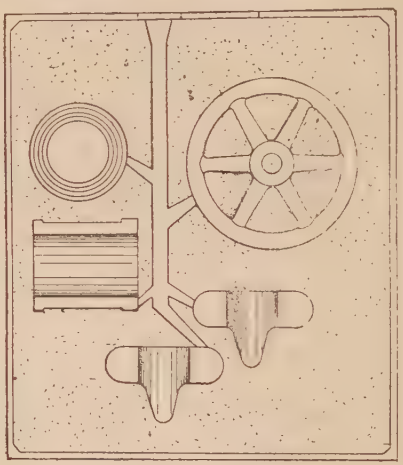


FIG. 126

much more care than if made for an ordinary mould, because it has to do duty for scores of moulds, instead of for one only. Weak corners of sand are avoided as far as possible, because these are liable to become broken, and detract from the accuracy of the mould. Odd-sides are usually rammed in dry sand, coated with wet blacking, and dried. When finished and strewn with parting sand, they are ready for service.

More durable odd-sides are made by mixing a drying oil with very finely sifted sand, and these are less liable to fracture and wear at the keen corners than those made of common sand or of plaster. Boiled linseed oil will answer, or raw linseed oil to which litharge is added, the sand and oil being thoroughly mixed and amalgamated. The weak sections of the sand should be strengthened with nails while the mixture is soft. It is best if air-dried,

but it may be safely dried in a warm place. The objection to plaster-of-paris as a material for odd-sides is the weakness of delicate corners. For this reason those of sand are preferable, for some classes of work at least.

Plated Patterns.—The mounting of patterns on plates is the highest development in moulding, following naturally from the use of a bottom or joint board. The plated pattern is merely one which is fastened to its joint board, instead of being laid loosely upon or let into it. This class of work is generally associated with the use of a machine; but there are thousands of plated patterns which are moulded without such aid, and the practice is also a very old one. Often, though not by any means even as a general rule, wooden plates are used when moulding is done by hand, and those of metal are put on the machines.

Plate moulding may or may not be costly—depending on various circumstances. But in this, as in other labour-saving devices, cost is purely a relative question. And the practice of plating patterns admits of great differences in detail, in order to accommodate either occasional or standard work. The bottom board of wood, with holes fitting to the pins of the moulding box, is as truly a plate as that of metal. And the wooden pattern mounted on this plate comes in the same class as the metal pattern which is fastened on, or cast to, its plate of metal. But in one case a few shillings may cover the cost of plate and pattern, in the other as many pounds. It will often be cheaper to put a wooden pattern on a wooden plate for even half-a-dozen or a dozen moulds, than to mould by ordinary turning over. And the economy will be of the same kind, though differing in degree, when many hundreds of moulds are taken from a highly-finished set of metal patterns mounted on iron plates. And therefore, though the wooden joint boards that have been illustrated fill an indispensable place in all brass foundries, yet they should give place to those of metal in those shops that have a large run of standard work, if the highest economies are desired.

Here, also, there are several degrees, if we may so put it, of standardisation. Thus a plate may be kept for use with one pattern for ever, or it may do duty for many patterns in succession, these being screwed on, and unscrewed, and replaced by others in a continual series as required. Such a system is economical both

of plates and of storage room; and as the various patterns go back at any time into their original locations, there is little time wasted in making these changes. This is just an extension of the same device that is commonly adopted also in the case of wooden bottom boards, which serve for several patterns or sets of patterns in succession, or else are retained for their own patterns specially.

Though details vary considerably in the work of plating patterns, the principle in all is to provide joint faces on the plates,

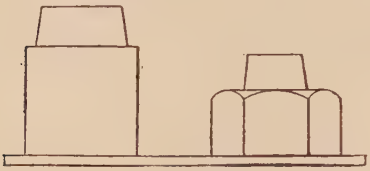


FIG. 127

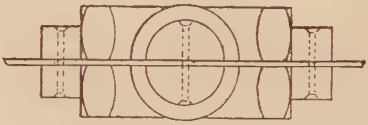


FIG. 129

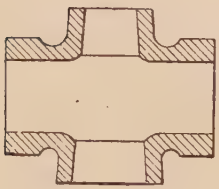
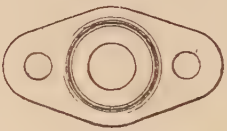


FIG. 128



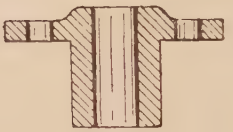


FIG. 130

against which the boxes are to be rammed, and so do away with the objectionable and wasteful method of making a false mould for no other purpose than to provide a reverse upon which the actual moulding shall be commenced. Thus far the plate fulfils the same function as the single odd-side.

Evidently, therefore, the plate is a very elastic device. But it may also be rigged up with its patterns, and also to its moulding box in various ways. The simplest is that in which a pattern or patterns go wholly on one side (Fig. 127), illustrating a nut and a bush, the other face being flat, so forming a plain top. Next comes the plate with portions of a pattern on opposite

faces. Thus the pattern of the valve body in Fig. 128 is shown mounted on opposite faces of the plate in Fig. 129; and the gland in Fig. 130 has its pattern mounted as in Fig. 131. Afterwards comes the separation of plates, two being used for a mould—one for the cope, the other for the drag—a case which admits of moulding by separate men, and a method which has advantages over the other, partly because two machines can be brought into service, partly because when there is much difference between the nature and extent of the work in the top and on the bottom box, such work is more economically performed when divided between two men, or a man and a boy. In another device one plate only is used, containing but one half a pattern, and two moulds from that make up the complete mould. In this case it is of course

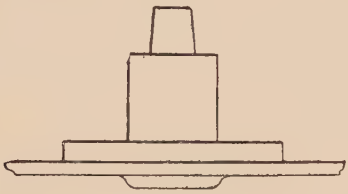


FIG. 131

essential that the pattern shall be symmetrical in all respects, because the moulds have to be turned over face to face. This, however, covers a large quantity of work. Finally, in many instances, instead of plain faces, the plates have irregular contours, to correspond with sloping and curved sand joints. In these the economy is greatest, as is evident by the parallel fact that it is in irregular jointing that the economies of odd-side are greatest. When patterns are very irregular the joints must follow a similar contour, and ten or fifteen minutes or more may be often spent merely in forming and sleeking the joint faces by hand in a single moulding box.

In considering plates, therefore, we observe that the differences between them correspond also with the character of the various joints employed in ordinary moulding, and with the differences in methods of moulding. Though the flat class of plate can be used for more than one pattern or set of patterns, the type which has irregular joint faces cannot, but must remain standard for its

own patterns. Generally in these last the patterns and plates are cast in one, but plates with flat faces are frequently cast separately from their patterns, and the latter are screwed or otherwise fastened thereto.

There is no mystery about plating patterns, although people who are but slightly acquainted with the relations of patterns and moulds are sometimes puzzled over them. Portions of patterns are seen on opposite sides of a plate, or on one side of two plates, and it does not seem clear how the moulds from these are made to match properly. This is, of course, the chief difficulty in plating —namely, to prevent lapping edges and fins—and it depends entirely on how the fitting is done, both that of the patterns to their plates, and the latter to the moulding boxes. The best way

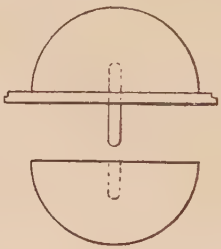


FIG. 132

to understand this is to imagine a common jointed pattern taken, and a plate interposed between the two portions without disturbing their relative positions. Say the dowelled half of the pattern has unusually long dowels, Fig. 132, and holes are bored in the plate to pass the dowels through. It is clear now that the interposition of the plate will not affect the perfectly plumb positions of the pattern parts, and that if a mould is taken from each half there will be no lapping joints. This, in fact, supplies the key to the making of pattern plates. These are simply inserted by some method or another between the pattern parts without permitting them to affect the correct relations of the latter. The case of fitting separate plates is not quite so simple, though the final result must be exactly the same.

The Plates.—It should be evident that the thickness of a plate does not affect the thickness of the casting, but it is determined solely by considerations of convenience and suitability. Made in

wood, a plate is thicker than if in metal. In large patterns plated in wood, the latter may be $1\frac{1}{4}$in., or even $1\frac{1}{2}$in., thick; in small patterns put on metal plates, the latter will not be more than from $\frac{3}{8}$in. to $\frac{1}{2}$in. thick. The condition is that the plate must be sufficiently rigid to withstand ramming without yielding and springing, which would fracture the sand. And if joint faces are not true, the risks of a crushed mould are present. Though the thickness of plates bears no relation to the finished mould, because they simply provide *faces* for ramming against, yet it must bear some relation to area. So while a small plate need not be more than about $\frac{3}{8}$in. in thickness, one of large size will be $\frac{3}{4}$in. Between these the thicknesses of most iron plates range.

Weight is a matter of less moment in the case of metal patterns and plates moulded by machine than in those operated by hand. In the latter especially it is necessary to lighten the large patterns also by casting them hollow. This can be done in many cases.

Cast iron is the best material to use for plates, but wrought iron and steel plate is sometimes employed, to save the cost of tooling the faces, which is necessary in cast iron. If wrought iron or steel are used they must be perfectly levelled, and even then they do not present so true a face as cast iron plates the surfaces of which are planed or milled.

A very economical way of moulding divided wood patterns of any dimensions is to screw the two halves on opposite sides of a wooden plate of suitable thickness, and drill holes in the latter to allow the pins of the moulding box to pass through and be cottered. The writer has fitted patterns of large dimensions in this way for iron castings, including columns up to 12ft. in length by about 18in. in diameter, and also large circular cast iron tank bottoms, and the device is equally applicable to patterns for brasswork, measuring only a few inches across, and to groups of patterns. The board is cottered between the box parts, and both sides are rammed up in turn. The truth of the joint edges in the mould depends on how the mutual fitting of pattern parts and board has been done. This device is not quite so favourable to free delivery of the pattern when work is moulded by hand as when separate plates are used. If, however, the plate is mounted in a machine, it is as suitable from the point of view of delivery as mounting separate plates.

The question of wooden patterns and plates *versus* those of metal often comes up for attention. Only in the case of those of large dimensions is wood employed, and not always for those, because it is difficult to keep such patterns true, being, as they are, nearly constantly embedded in the moist sand, and subject to occasional blows from the rammer, and pricks from the vent wire. In brass foundries, patterns of brass are mostly used, as those of iron predominate in iron foundries. White metal is also used. A greater advantage which these patterns have over those of wood is due to the difference between withdrawing patterns on plates from the sand, whether used with or without a moulding machine, and withdrawing them singly when free from a plated connection. In the latter more complete ramming can be done, and faces lifted which cannot be so readily lifted when the pattern is on a plate. There are, on the other hand, disadvantages due to excessive rapping, which the plating process lessens; but then it is necessary to bestow more care on the vertical and nearly vertical faces, and deep faces of plated patterns, than on those which are moulded by common methods. Here, too, the question of stripping plates comes in. It may be laid down as a wise rule that where a fair amount of taper is not objectionable it should be imparted to patterns for plate moulding. Where this cannot be given, there is all the more reason why metal should be used in preference to wood, as not being liable to distortion, and in certain cases the use of stripping plates becomes essential.

Putting patterns on plates sometimes renders some departure from usual methods of moulding either necessary or desirable. Thus a common device adopted with a view to a cleaner lift is to make sloping joints in certain cases. In plated work the fewer these are, as a rule, the better, so that patterns are often made with plain joints for convenience of putting them on a plate, which if moulded by common methods would be done with a sloping or an irregular joint or joints. The inconvenience of dispensing with the latter is then often compensated by the more favourable conditions for lifting which accrue from moulding with plates in conjunction with a machine.

Again, the false cores, or drawbacks, that fill so important a place in brass moulding are better dispensed with when work is plated, and dried cores made in boxes are largely substituted,

fitting into the impressions of coreprints. Coring, too, must often be done to permit of the moulding of work which in ordinary moulding would be accomplished by the aid of a middle box part.

Methods of Mounting.—The methods of mounting patterns on plain plates are as follows:—In Fig. 127 they may be soldered on, or screwed, or cast, the first two being preferable. In Fig. 129 the halves are riveted through as shown. The rivet holes are drilled first, the halves being soldered together temporarily, or riveted temporarily, while they are being filed and cleaned up. In Fig. 131 screws are used, or rivets, or solder. Fig. 133 shows a pattern screwed together. Stove screws are employed, and they are inserted in the pattern before the insertion of the plate, as

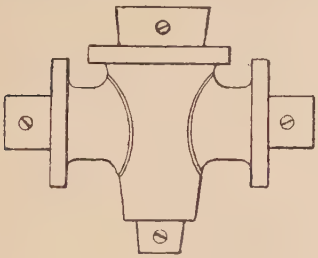


FIG. 133

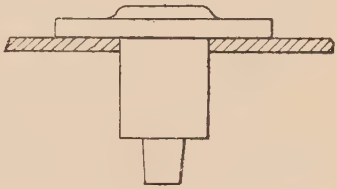


FIG. 134

with the rivets in Fig. 129. Another way, when the shape will permit of it, is to drill holes in the plate and pass the patterns through, and screw or solder them (Fig. 134). The portion of the pattern which goes through must be longer than the casting by the exact thickness of the plate.

Casting Solidly.—Pattern plates are often cast whole with their patterns, as being cheaper than fitting the pattern parts to planed plates with screws or rivets. The underlying principle is simple. A mould is made complete or in part, according to whether the patterns are to be cast on one side or both, and the mould of a plate is included, to be cast in its proper relation to the work. If the joints are irregular and the patterns solid, then an odd-side may be used, or a mould prepared similarly. If they are plain and the pattern jointed, a bottom board is suitable.

A mould may be taken from an odd-side in the usual way—that is, the drag will be rammed on the odd-side and lifted off,

the patterns put back into the drag, and the top rammed. Similarly a mould may be made by the ordinary methods of turning over, the patterns being bedded in the top, and the joints made with special care, because they will be permanent in the plate, and any insufficiency of slope or tendency to undercutting would be a perpetual source of annoyance. Then the drag will be rammed and turned over, and upon it the cope. Or if the joint is to be

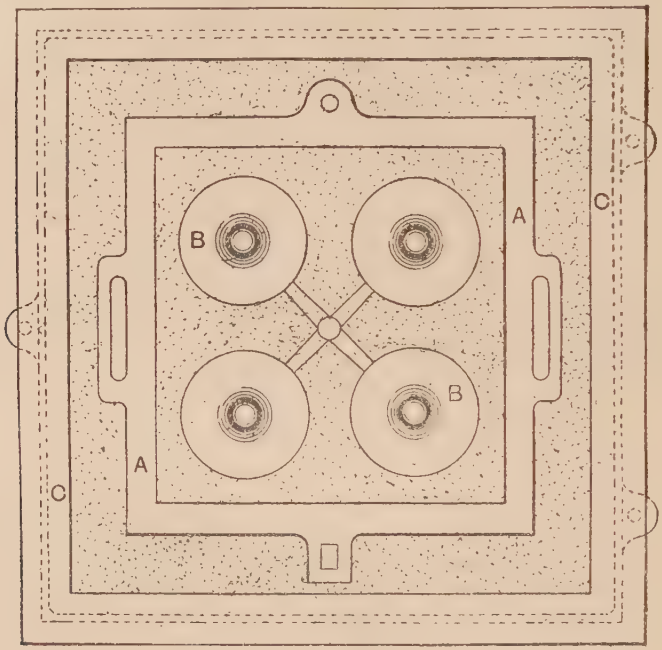


FIG. 135

plain, the patterns, if jointed, may be arranged suitably upon a bottom board, and the drag rammed thereon and turned over, and the top rammed.

Up to this stage, in each instance the work is like that of ordinary moulding, only that some extra care is taken. The mould is now parted, and the runners cut, if they have not already been taken from pattern runners placed in the mould. The patterns are left in the bottom for the present, while provision is made for the making of the plate.

Bearing in mind the fact that the insertion of a plate between

pattern parts does not in any way affect the shapes or relations of those parts in the finished mould, all that we have to do is to mould the plate of any desired thickness around the mould of the patterns. This is done by making a pattern of the plate to the thickness settled on, and having the outlines which have to correspond either with the moulding boxes used or with the table of the machine. Thus, Fig. 135 shows a pattern plate A for a hand-made mould, and which is now laid upon the bottom moulding box just encircling the patterns B. Outside of this the sand will be rammed to give the outlines of lugs and edges, so forming that portion of the mould; and the sand will be strickled off very carefully exactly level with the top face of the frame C. The inner edges of the frames A and C are of no importance, since they have nothing to do with the actual mould, which is already formed by the patterns and their joints.

In ramming this frame a separation has been effected between the upper and lower portions of the mould by an amount exactly equal to the thickness of the frame C, so that they will not go together by that thickness. To prevent the sand from crushing, strips of iron may be used of the same thickness as the frame C, and laid between the box joints for pouring. But a better plan is to use iron frames C for this purpose, a little larger than the boxes. Standard frames can be kept of different sizes for making plates from. These frames will be exactly the same thickness as the moulding plates are to be; they serve to keep the boxes at the exact distance apart, and to confine the sand which is rammed outside the actual moulding plate, as in Fig. 135. These frames should be planed on both sides. After the mould is completed, the frame remains in place during the pouring.

Pattern plates made in this way depend for their accuracy chiefly on the care with which the moulding has been done. If the plates or patterns, or joints, come out lumpy or drawn they cannot be tooled as though the parts were all prepared separately, and it would be better to cast them afresh than to spend much time upon them. A little filing and polishing is all that can be attempted on solid pattern plates. It is well when plates are to be used for hand moulding to cast hand slots at opposite sides as in Fig. 135, A. They do not come in the way of anything, and are very convenient, especially when the patterns are rather

heavy. Lighter plates are cast as in Fig. 136. Boxes are usually fitted with round pins entering into drilled holes. In an ordinary foundry scarcely any two boxes of the same size nominally are alike and interchangeable, but the pairs have to be kept separate, or if box parts can be changed about, it is only by reason of their looseness of fitting. In a good system all boxes would have the holes drilled and reamed through a templet, so that any parts of the same size shall interchange with each other, and with the pattern plates or the machines, as the case may be.

The good fitting of boxes is more essential in machine moulding and plate moulding than in hand work, because in the latter a

FIG. 136

moulder gives a badly-fitting box a twist "sun road" to cause the pins to fit their holes on one side only, or he marks lines across from one box to the other on the outside with the trowel on a whitened or a loamed surface as a guide to set the boxes by, both when ramming and when closing for pouring. But such adjustments are not possible when plates are used, but the boxes must go together just as they happen to come.

In many boxes for plated work a compromise is effected—one pin only fitting closely, the other fitting sideways only. In such cases the pins are cast on the box lugs as being cheaper than drilling, and while the closely-fitting pin is round, the other is square, fitting in an oblong hole. This is the device shown in Figs. 135 and 136.

CHAPTER VI

PATTERNS

Tooling Allowances.—The allowances on patterns for tooling are usually small, being half or less than half those given for iron, ranging from a mere film required for polishing, to less than $\frac{1}{32}$in., and up to $\frac{1}{16}$in. where turning, boring or milling have to be done. The smaller the casting the less is the allowance, because there is no trouble with variation in shrinkage. On metal patterns, and on those that are plate-moulded, the allowance is less than when wooden patterns have to be moulded on the bench or floor. The shrinkage of brass may be taken approximately at $\frac{1}{8}$in. in 9in. or 10in. This is an average only, and other allowances must be made in cases where experience tells us that varied mixtures of metal, or green, or dried, and heavily-cored moulds, and other causes, may be expected to influence the shrinkage. Causes that lessen shrinkage have to be considered in large work. Hard cores in a mould have this effect. This is of no consequence in small work, but it is in that of large dimensions, and therefore it is sometimes necessary to allow more, or less, than usual, in large work that has to be bored and turned to exact sizes.

Metal v. Wood.—Metal patterns are cast from wooden ones, to which double shrinkage allowances are given, in addition to allowances for tooling both the metal patterns and the final castings. Made with little regard to finish, in pine, to be used for taking only one or a few moulds from, they are of no further service. Metal patterns are expensive, because they have to undergo tooling all over in the lathe, planer, milling machine, or on emery wheel or buff, or filing, and mostly to fine dimensions. They are tooled very exactly, with allowances in favour of taper where required, as at the ends of cylindrical work moulded flatwise, and in the holes of shallow patterns which deliver without

coring. As several patterns of the same article have often to be arranged on a single board, whether plate-moulded or not, or in odd-sides, their preparation is costly, because each pattern has to be got up in uniform style and to uniform dimensions. In the case of small patterns, in which the shrinkage is practically nil, one can be tooled up carefully, and then other patterns moulded directly from that, and merely filed up or ground and polished. But this is inapplicable where shrinkage comes in.

When moulding large quantities of similar work several alterations sometimes have to be made before the most satisfactory results are attained. Metal will be in excess in some places, skimped in others. Allowances for tooling will have to be increased or reduced. Cored work gives much trouble when at all intricate, and the pattern or box may have to be returned to the patternmaker several times before exact results are secured. But the great advantage of metal patterns is that when they are once got right they remain permanently so, while wood, though well seasoned, will lose some of its accuracy in time, however well cared for, partly due to its absorbent nature, and partly to the effects of ramming and the use of the vent wire and swab.

Of the larger classes of work it may be stated broadly that the question of metal *versus* wood patterns is one of convenience more than of necessity. But there are many small flimsy patterns that must be made in metal because they are too thin to be of service in wood. Rings for the pistons of small pumps form a large class to which this remark applies. Such articles, typical of many others, are too small to be jointed up in segments, and if made in the solid the short grain is a source of weakness and cause of shrinkage. Rough wooden patterns are necessary in the first place for these. Patterns of ring seatings for the small valves, and much other small work, can be often made without a wooden pattern, from pieces sawn off large ingates, or rough blanks can be cast from stock prints or runner sticks for the purpose.

The most expensive patterns to make are those which are attached to plates. They are, when jointed, dowelled or screwed together, fitted like a jointed pattern in wood, and the same screws or pins, or similar ones that hold them together, pass through and unite them through the plate and ensure an even joint without lapping in the mould.

Metal patterns are either made in brass or of a white metal composition. The quantity of metal thus stored accumulates, but like the cast iron in moulding boxes it is always of value for melting up when done with, and they can be cast on the premises under supervision, while iron would generally have to be sent out. Patterns can also, except in the smallest sizes, be cored out, and thus lightened to a considerable degree. But though the weight of brass thus locked up will run into many tons in a stores, the necessary expense must be borne, since wooden patterns cannot stand the incessant usage demanded, and would have to be frequently renewed at great cost. Another important point is that wood can never be relied on to retain its shape and dimensions absolutely, and since the allowances for tooling are cut very fine in brass work, a distorted and badly worn wood pattern could not be relied on to produce castings of correct shape and dimensions.

White metal is used for coreboxes, where it is not so liable to become knocked out of shape as in patterns, because the mass of metal surrounding the hollow portions of the boxes keeps it rigid. Wood is ill-adapted for coreboxes, because the thickness of metal is cut as thin as possible in brass work, and a distorted core would alter the thickness.

Methods of Constructing Patterns.—When patterns having one or more branches are constructed in wood, there are two ways of making them, one by jointing the pieces together (Fig. 137), the other by cutting mainly from the solid (Fig. 138). The great advantage of the first method is that it permits of turning of parts in the lathe which cannot be done in the second case, and that patterns so made are not so liable to go out of truth as the latter, because there are two or more pieces with different arrangements of grain, instead of one. The advantage of cutting in the solid is that it is easier to mark out and cut everything, than to ensure the accuracy of the fitting of separate parts; that there are no joints to become loosened by moisture and rapping; and that all hollows or fillets can be cut in the wood. The question in any given case must be settled by judgment and experience of similar cases. Sometimes it is better to joint, sometimes to cut from the solid. When joints are made, the method of dovetailing as applied to pipe work can be adopted to a limited extent. So, also, can

that of fitting round curves with an abutting joint, Fig. 137. If a pattern is divided the joints should be made on a level board, and glued upon it to preserve the parts in position. It is safer to glue and let it set hard before putting in screws. The glued joint can often be assisted with dowels tightly fitted and glued also.

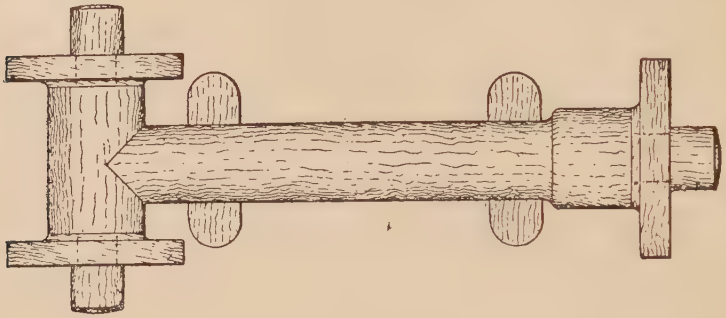


FIG. 137

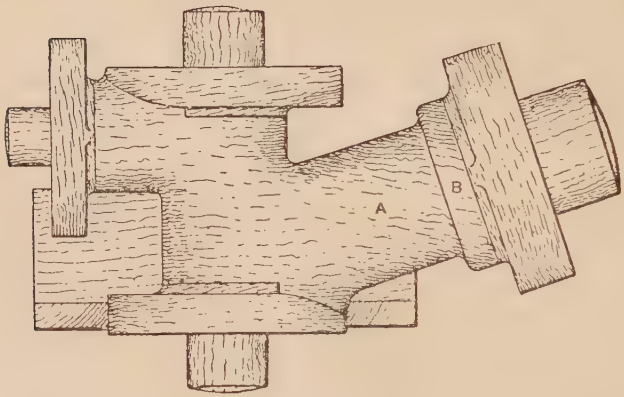


FIG. 138

When making patterns from the solid it is advisable in most cases to turn prints on bodies, and to turn such other portions as will admit of this method, both to ensure accuracy and to cause some of the turned portions to serve as guides for the cutting of the remaining parts by hand. Thus, in turning a globe valve by this method, two chuckings at right angles are made. In the first chucking the faucet ends have their prints turned, and the hexagon portions are turned over the tips of the hexagons, and the shoulders

also behind the hexagons, and as much of the commencement of the globular portion as can be reached by the tools without being interfered with by the spindle branch. At the second chucking, the latter and the parts adjacent are treated similarly, leaving the main portion of the globe to be cut by hand. In Fig. 138 the parts marked A, B might be turned very well, and all the prints could be turned, and the flanges fitted with turned shoulders, though that is not the method illustrated. A detail in pattern work which calls for remark relates to the hollows or fillets inserted in angles. When but two or three castings are required it is usual to omit them from the pattern, and leave them to be rubbed off in the mould. When a fair number of castings are

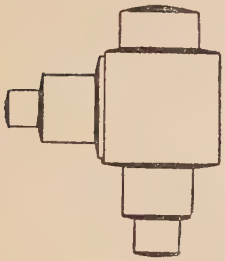


FIG. 139

FIG. 140

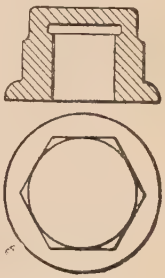


FIG. 141

wanted these should be invariably put on in the pattern, because, besides the saving of moulder's time, the castings will be all alike, and the fillets more regular than when sleeked in the sand. The brass founder is catered for well in this respect, fillets of leather and of metal being supplied in various sizes, which can be laid round curved portions as well as straight ones. Failing this, beeswax makes good filleting.

There are some sections of brass moulders' patterns in which taper is desirable, others in which it is not well to have much. More taper, as a rule, can be given to parts which have to be tooled than to those which have not. The ends of patterns, Fig. 139, adjacent to the prints should usually be well draughted, because the lift is awkward here, and the sand is sometimes apt to crush also, by the insertion of the core and closing of the top, if left too square. The holes in parts that deliver themselves, and which also have to be tooled, should be well tapered, and

there is no objection to this, because the roughing-cut in the lathe or drill takes out the extra material. If taper cannot be given, then work, though shallow, had better be cored. Thus, the hole in the brazing flange, Fig. 140, would deliver with scarcely any taper, although a considerable amount would not be objectionable. But the hole in the cap nut, Fig. 141, even supposing the tool clearance were not there, would not deliver without much taper. In this case the hole, with the clearance, would be cored.

Cores are often used even in shallow work, because they afford either the only or the best method of forming ribs or internal rims. Figs. 142 and 143 are cases in point. The alternative in some cases, though not available in these, is to lift the internal sand in the top part, a device which is not a good one, except in work where the lift is very shallow. Even then taper is required, and too much of this is objectionable. But a lift that cannot be made safely by hand can often be made by machine.

FIG. 142

FIG. 143

There are a few cases in which patterns can be lifted by hand which cannot be lifted by machine. Those types of wing valves in which the wings run diagonally, and valves where the ribs connecting boss and rim are set diagonally, each with the object of making them turn a little on their seats when lifting, can be drawn by hand. The simple device of twisting them in the act of withdrawal effects this. But the diagonal shape prevents them from being lifted by a machine, in which case they could be formed in a core or cores.

The larger the number of castings wanted off a pattern, the greater care must be taken to see that the prints and those parts of the boxes which have to correspond therewith do so. In most iron moulding it is generally advisable to make core prints very slightly larger than their boxes. In small brass work they should be exactly the same size, and some moulders like to have them just a shade smaller. The reason is that the pattern is rapped just a trifle, which enlarges the impression of the core print, while the rapping of the core box makes the cores a trifle small. In

the case of tapered prints the taper should be put into the boxes, and not left for the moulder to rub. Horizontal prints, of course, have no draught, but their ends should be tapered amply, not being working parts (*see* Figs. 137, 138 and 139). If left square the ends will tear up the mould and give needless work.

In nearly all cases round prints should be turned in one with their bodies and not fastened on afterwards. If a flange having grain in the opposite direction comes between the pattern body and the print, the latter should be continued from the body and the flange bored to fit into a groove. This is done in Fig. 137, but not in Fig. 138. It might be done in Fig. 138 by chucking the body and turning the prints and grooves out of the solid.

Cores.—Coremaking in standard repetition work is very much a matter of routine. Cores are not made as a general rule by the moulders, but by youths who afterwards go to moulding. In some foundries girls are employed in this work in a room by themselves, and soon acquire dexterity in the work required for the particular speciality of the firm. In special and untried classes of cores such is not the case, but details have to be planned by the light of previous experience. There are many points involved in coremaking for brass work, including accuracy of outline; selection of the suitable sand and its mixing, and method of ramming; the stiffening of the cores, their venting and drying.

In reference to the making of cores, the selection of sand is a kind of compromise. A coarse sand is good for venting, and is suitable for cores of large sizes. Finer sand is used for small cores. Generally the same methods of stiffening and venting are used as in cores for iron. All except the tiniest must be stiffened with wires, or with rods running longitudinally, and following curves where weak sections of sand have to be carried. Weak parts are also, like moulds, stiffened with nails. Straight vents are made by the vent wire, or by rods, drawn out subsequently. In curved parts vents are made with strings. Large areas are filled with a body of cinders into which numerous small vents collect, and out of which they are brought.

In ramming cores the aim is to strike a mean between hardness and rottenness. Sand wetted and rammed too hard produces hard cores on which the metal bubbles. Cores must be dried entirely in the stove, and should not be inserted in the moulds

until just previous to pouring. If cores are exposed long to the air they become rotten, and in the mould they absorb moisture, and are liable to cause blowing. Cores must be dried in the stove until the particles of hay in the manure become desiccated, leaving natural vents throughout. Many core compounds are sold for the purpose of binding the sand firmly. The natural cementing materials or glues used in the brass foundries include rosin, molasses, pea flour, sugar, beer grounds, and others, rosin being most commonly used.

Coreboxes.—First, with regard to accuracy. Although cores can be distorted by careless handling before drying, accuracy is chiefly a question of the corebox. There are two classes of boxes,

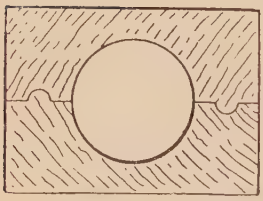


FIG. 144

FIG. 145

FIG. 146

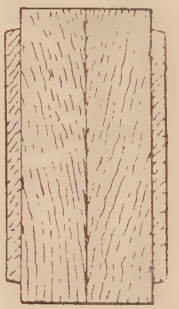


FIG. 147

the standard and the special. Standard boxes can only be of two kinds—round and square—because these are the only shapes that are being constantly repeated in the foundry. They are so important a section of the work that the question of the best boxes to have is not always solved in the same way. It is understood that boxes the halves of which are dowelled are not the best possible, because the dowels and their holes work loose with usage. Neither are wooden boxes entirely satisfactory, since they wear rather badly near, and at the ends, due to the constant friction of the rammer and the application of the swab; and they get out of truth in consequence of the absorbent nature of the wood. When used, they are best checked together by registers running throughout the entire length, as in Fig. 144.

To make such boxes, the interiors are planed as nearly as possible to shape with "round" planes, assisted by the paring

gouge at the nearly vertical sides. Then a rubber is turned nearly to the size of the bore, being less than that by the thickness only of a sheet of glasspaper. A saw kerf is made along it (Fig. 145), and the sheet of glasspaper inserted and wound round the stick. This is then revolved between the lathe centres with the box encircling it, the latter being closed tightly round the rubber by the hands. As the stick rotates, the box is traversed slightly lengthwise, with the result that the hole will be finished very true throughout.

When a box becomes damaged by long service it can be re-jointed and re-bored, or a new one made. The best preservative is plenty of varnish applied from time to time. Boxes can be prevented from curving due to the removal of the stuff

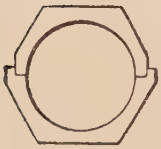


FIG. 148

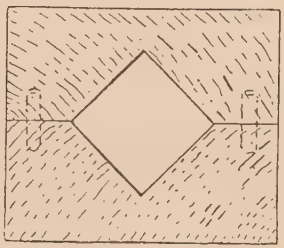


FIG. 149

for the hole by battening them at the back, as in Fig. 146 or Fig. 147, and the box can be rapped against these battens to loosen the core previous to opening the box for its removal. Boxes thus battened and made of sound, well-seasoned mahogany and varnished or painted on the outsides as well as in the hole, to be thoroughly impervious to moisture, will serve for making many thousands of accurate cores in.

Even iron boxes lose their truth in time owing to the friction of the rammer and of the sand. But for standard work the iron boxes are much the better. Fig. 148 shows one of these in end view, with a registered joint throughout its entire length. It is not heavy, remains accurate for many years, and is unaffected by moisture or warmth. These boxes have planed joints, and the holes are bored. After several years' use they can be re-planed and re-bored.

Standard boxes of square section are made in two ways, either by cutting the hole with a rebate plane in the solid stuff, Fig. 149, or by framing an open box, which must be laid on a level bench during ramming, and the sand in which must be strickled off on the top face. There is no great advantage in making the box as in Fig. 149, but it is not open to the objection of the second type, Fig. 150—namely, that the sides in this will bulge outwards during the ramming of long cores unless they are either made of thick stuff or stiffened with a rib. Boxes are commonly made in both ways.

As regards the great differences in the lengths of the cores required in a foundry: lengths are generally cut off either in the

FIG. 150

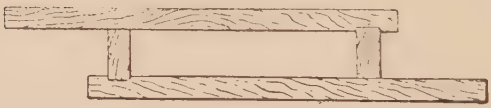


FIG 151

boxes while the cores are green, or they are sawn off after drying —it does not matter which. Square boxes are sometimes made to slide, as in Fig. 151, so that the length of core is rammed at once. Here, also, there is little advantage gained, because cores can easily be sawn to the neat length required.

Chambered cores for recessed holes are in frequent request. These cannot be made in the standard boxes; that is, recesses cannot be cut in the boxes without spoiling them for straight cores. To sweep up single cores against boards is too expensive. When chambered cores are wanted they are generally made specially for their jobs. But the standard boxes can be utilised by fitting shells into them as in Fig. 152. Say a 1in. core has to be chambered to 1½in. Then the 1½in. standard box is taken, and pieces fitted in 1½in. diameter on the outside, and 1in. bore, and laid in the box, and secured temporarily with small screws.

The halves of coreboxes are held temporarily during ramming with clamps. Three common forms are shown in Fig. 153. A is of square iron bar, bent round; B and C are two forms in wood. A liberal supply of the iron ones is necessary on the core bench. The smallest iron boxes are held by one hand alone, while the other is used for ramming. In some foundries special screw clamps are used, having power of adjustment to suit a wide range of boxes.

Special coremaking machines are made by means of which

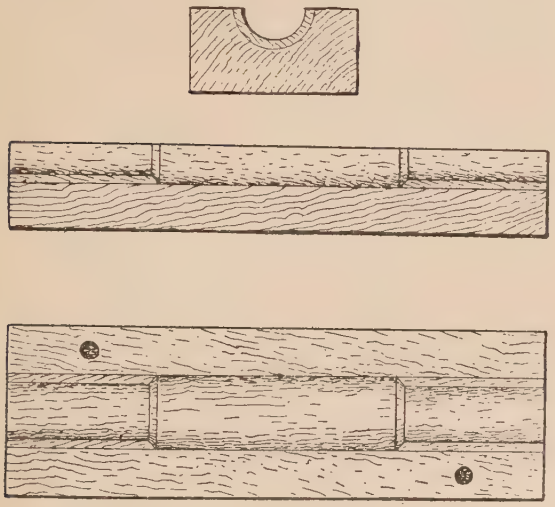


FIG. 152

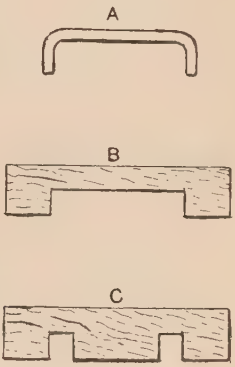


FIG. 153

cores of any length can be rammed. The boxes are undivided, and the cores when finished are thrust out endwise.

Prints for other subsidiary cores have to be put into many coreboxes. These should be varnished of a distinctive colour to indicate that they are not to be cast as metal. Such precautions may appear unnecessary to the machinist, who considers the particular uses of castings, but it must be remembered that moulders are not machinists, and although in the standard work of a foundry the men know what to look for, they cannot be expected to understand the intricacies of the large volume of work which is brought in from outside.

When metal coreboxes are made it is not usual to lighten them in the way, or at least to the extent, that the corebox in Fig. 148 is done. They are lightened a little, being reduced rather below those made in wood, but not much. If cast in brass the metal is cut down considerably, but in the softer white metal mass is an advantage as preventing the boxes from becoming battered out of truth. Such boxes may be cast over a plaster core within a frame. Or they may be made from wooden boxes with a little allowance for cleaning up. But before casting them, a core should be made from the wooden box, and necessary corrections made; otherwise it might be necessary to cast a second metal box, or spend more time than it is worth in correcting it. We shall say more about these matters in connection with examples of work.

Methods of Working Boxes.—In reference to special boxes, the care bestowed upon the preparation of these should depend chiefly on the number of castings required, and the limits of accuracy thought necessary. A good mahogany corebox, carefully marked out, and cut by the aid of templets, and altered slightly if necessary after a core or two have been tried in the mould, is good enough for very much work. A considerable degree of care is required in making boxes for the more intricate cores when metal is cut finely. The larger the core and the thinner the metal the more carefully must the core and the pattern, or the core and the mould, be checked in relation to each other.

A common method of working when the nature of the job permits of it is to lay the half pattern with its joint face on the joint face of the corebox, and mark the pattern outlines clearly on the box, and then mark the core outlines within them, by which lines the box can then be cut. The correspondencies of the two as far as the joint is concerned are then clearly seen, and as regards the other portions lying below the joint face, measurement and the aid of templets are called in. When a pattern cannot be laid upon its box joint, both the pattern and the core outlines must be marked directly off from the drawing. This marking out, when done deeply, and when the thickness of metal is deeply shaded also, becomes sometimes in intricate work an aid to the moulder when several cores have to be set in mutual relations, as well as to the patternmaker. Several templets have often to be made

for intricate boxes, as they afford nearly the only reliable means of shaping to precise dimensions away from the joint faces.

To ascertain the thickness of metal in small brasswork, where, in consequence of the quantity required, it is desirable to skin the metal and reduce the cost as much as possible, it is often the practice to make a casting in lead or tin and saw it into various sections, and note the thicknesses, altering patterns and boxes accordingly.

Carver's tools are of great service in cutting into the deeper parts of coreboxes, partly because they afford so large a variety of curves and angle, and partly because many of them are bent, in consequence of which the bottoms of boxes can be reached which cannot be got at so well with straight tools.

In fitting coreboxes, loose pieces will frequently have to be inserted. In repetition work such fittings are best attached with sliding dovetails rather than with skewers. Nothing should be left to chance when many similar castings have to be made. The holes for skewers may be unnoticed, and the loose pieces omitted in consequence. Dovetails cannot fail to be seen, indicating by their presence the location of loose pieces.

It is well, when sending patterns out to be cast, to make a distinction between core prints and metal by adopting a different colour, such as black for all prints. It is, however, less necessary in brass work, for which core boxes are generally supplied, than for some iron work that is plainly cored, and for which core boxes are frequently not sent.

When loose pieces are attached to patterns, whether with dowels or dovetails, they should be so fitted that they cannot be put on in incorrect positions. The moulder does not always detect a wrongly-placed piece, and it is hardly his business to do so. The patternmaker should see to that.

The necessary parts for swept-up work must be prepared by the patternmaker similarly to parts for iron, by means of boards and sweeps, etc. Large liners for pumps are frequently made without full patterns.

Protection of Patterns.—The protection of patterns is second only in importance to their construction. The life of a wooden pattern, well protected and cared for at intervals, will probably be three or four times greater than that of one left unvarnished.

The art of preserving patterns of wood consists in closing up the surface grain so effectually that no moisture can penetrate beneath it. The secret is to lay on thin coats only of varnish in succession, and then to preserve the surface intact as long as possible from injury by rammer or rapper, or vent wire or spike. As many as three or four successive coats are applied, and the grain glass-papered down between each application. From time to time, after a few hundreds of moulds have been made, the patterns should be repaired and re-varnished. It is better to do this than to make new ones. A very good preservative is vermilion powder mixed with the varnish. It forms a hard and glossy skin, which resists the rammer and vent wire better than a plain varnished surface, and is impervious to damp.

The coating that protects also facilitates easy delivery, negatively by preventing rising and roughening of the grain, and positively by affording a glossy, slippery skin, which is favourable to the mutual separation of the sand and pattern. But this is further increased by the use of the blacklead brush, common blacklead or the plumbago of the foundry being used, and brushed at frequent intervals over the varnished surface. There is nothing better than this for patterns.

Wooden patterns of large size are sometimes protected with paint instead of shellac varnish. The advantage is that paint forms a harder skin than varnish does, and makes the pattern so much the more durable. Varnish may be applied over the paint to produce a gloss, and so may blacklead.

When patterns are made of metal, they, too, can be protected with shellac varnish. But this is not so good as some other substances, because it does not cling well to polished metallic surfaces. Beeswax is better, melted and rubbed over with a rag, the patterns being warmed first. Then the surface is well brushed to produce a high degree of smoothness. The same remarks apply to iron as to brass, but iron must be rusted before any application of either varnish or beeswax. It is rubbed with a solution of sal-ammoniac in water and allowed to dry. The rust thus formed is then lightly rubbed with flour emery cloth, and the beeswax or the varnish applied. Patterns should not be used very soon after being varnished or beeswaxed, but a few hours or a night should elapse between.

Names and register letters are frequently cast on standard brass work. The letters are either cemented on the original wood pattern and cast on the metal one, where they are got up with file and chaser point; or they are soldered on the actual metal pattern. When the latter plan is adopted, it affords a better chance to get up the surfaces of the patterns. But it is also open to the objection that soldered letters may become knocked off, and not be missed until a batch of castings has been made. Of course, their absence might be noticed, but such is not always the case, and prevention is better than cure, and casting on is safer.

Examples: Cocks.—Fig. 154 illustrates a pattern cock body

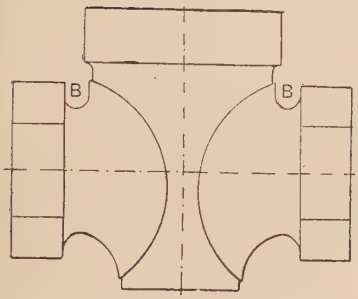


FIG. 154

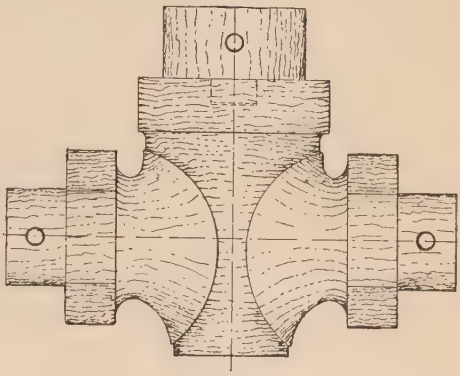


FIG. 155

made in the design which is termed a shield. The simplest way in which to make the pattern would be to turn the tapered body and fit the branches to it. This can be done, but it is not strong or durable, while much short grain would be unavoidable. Such a pattern is better turned in the solid (Fig. 155). If small, it will be unjointed and moulded on a joint board. Larger sizes, and those for plating, will be jointed along the middle. Fig. 156 shows the appearance of the pattern after it has been turned. First the branches are turned, and as much of the radius behind the hexagonal ends as corresponds with B, B in Fig. 154. The ends are turned to the exact size of the hexagons over their angles. Then the pattern is rechucked at right angles, and as much of the ends of the tapered body turned as possible, leaving

a central portion A to be cut with chisels and gouges. The slight amount of turning of these ends indicates to the workman where to start cutting exactly, and the eye alone is sufficient guide for working the taper and the shield. The print for the plug

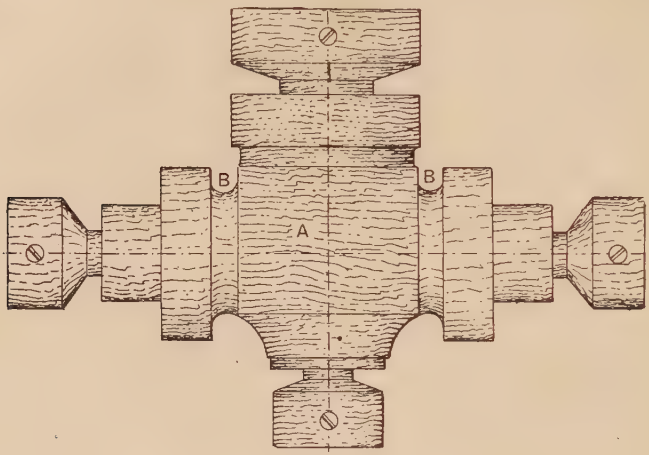


FIG. 156

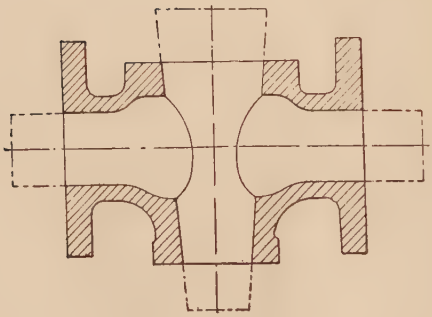


FIG. 157

hole is fitted the opposite way of the grain as shown in Fig. 155, to lessen the width of plank-way of the grain by that amount, and with it the risk of shrinkage or curving.

A cock of another kind is shown in Fig. 157, its pattern in Fig. 158, and its pattern body turned in Fig. 159. The latter is seen with recesses for the branch flanges. The flange at the top

of the tapered body is fitted separately (Fig. 158), and its print fits against the flange, being centred with a stud. The bottom print is also made separately. The only advantage in the chucking at right angles in this case (and it is sufficient to justify it) is to shoulder in the curves at A and B as guides for cutting the tapered body across. The flange attached to the face C is

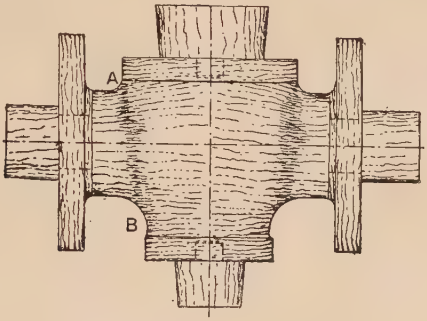


FIG. 158

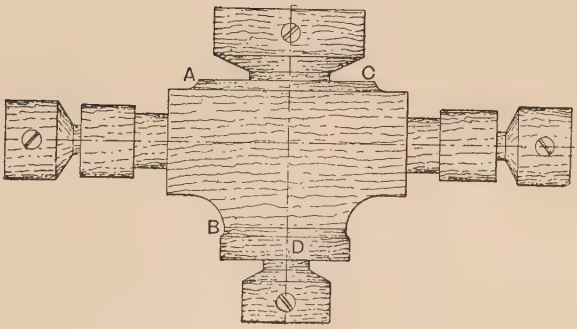


FIG. 159

square to receive four bolts. Its corners are removed with a large radius. At D there is a gland-shaped flange with two bolts. The belt there corresponds with the minor diameter of the flange, and lugs may be fitted on at D on both sides to form the gland shape and receive the bolts. Or the belt may be turned large enough to cut the flange from. A half corebox is shown open in the joint face, Fig. 160. As the box is symmetrical, a half-box would suffice for a few cores, but such practice is not usual in small cocks, though commonly adopted in large ones.

Note that the prints follow the taper of the plug hole. The box is shown as made of metal (iron, brass or white metal), as most

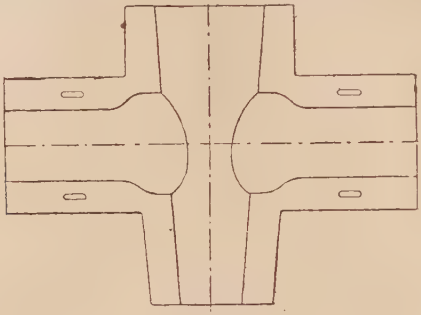


FIG. 160

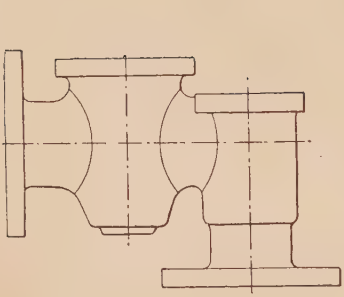


FIG. 161

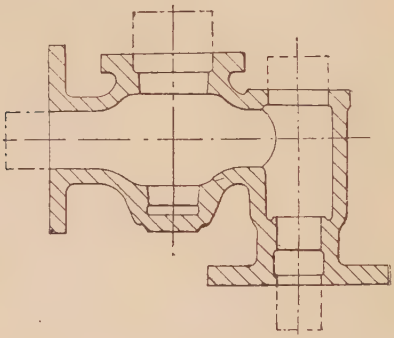


FIG 162

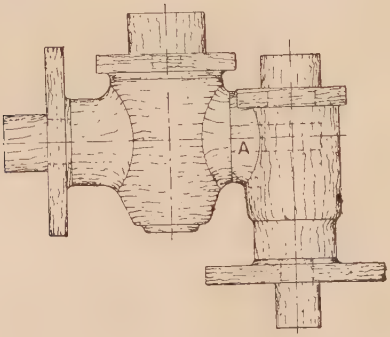


FIG. 163

small patterns also would be made from these, first constructed in wood.

The combined gland cock and check valve, Figs. 161 and 162,

is best made in the way shown in succeeding illustrations. It is the strongest way, and permits of most of the work being done by turning. The body of the cock is made distinct from that of the check valve, and fitted to the latter with a stem as in Fig. 163. The two portions are shown in Figs. 164 and 165 as they appear when taken out of the lathe, the first being for the cock body, the second for the check valve. The stem at the right-hand end of Fig. 164 is fitted into the body in Fig. 165 in the manner indicated by the dotted lines in Figs. 163 and 165. The piece A, Fig. 163, giving a radius, had better be made as an entirely

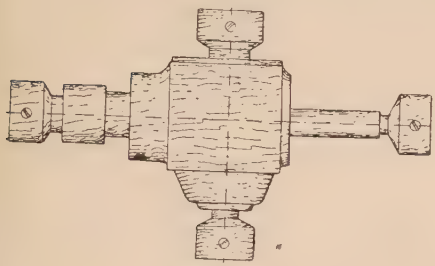


FIG. 164

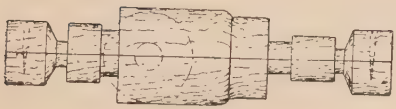


FIG. 165

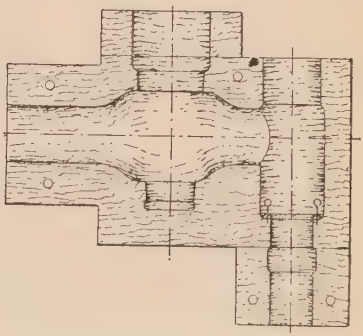


FIG. 166

separate piece fitted around the body of the check valve, and having a flat face for the shoulder of the cock body to abut against. The pin passes through this into the check valve body, and being glued and screwed, makes a firm job. This piece A has to be cut to fit up against the square flange, which with the cutting of the curves involves hand-work. The piece A could be cut from the solid in one with the check valve body, but then very little of the body could be turned, and a separate fitting of A is perfectly secure. The taper of the cock body is worked by hand, guided by the narrow zone turned at each end of the tapered portion, Fig. 164.

Half the corebox open in the joint face is shown in Fig. 166. It must be well battened at the back to prevent curving of the wood. It might alternatively be made in metal.

Stop Valve.—The double branch stop valve, Fig. 167, may be constructed as shown in Fig. 168, which is the joint face laid open. An alternative is to let in a piece of bar iron in the joint face, or a parallel strip of wood.

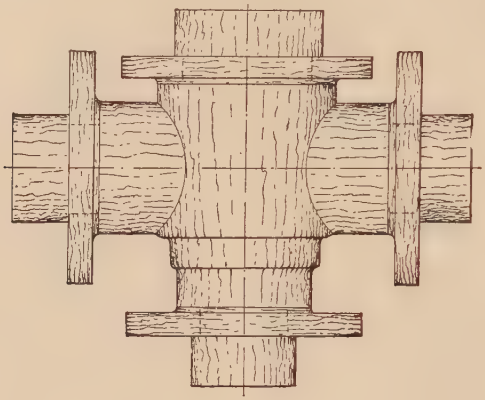


FIG. 167

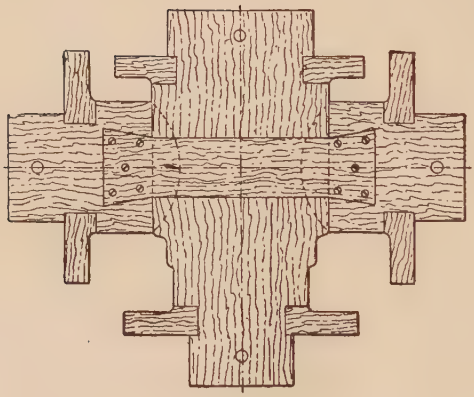


FIG. 168

The body of a brass casting is shown externally in the two views in Figs. 169 and 170, and in section in Fig. 171, which combines in one a stop and check valve, A being the body and seating for the first, B that for the second. The delivery branch C is at right angles, and made either right or left-handed as required. This involves two joints in the pattern and mould, one

being along the middle plane *a*—*a*, the other along the back face *b*—*b* of the flange C, as indicated in the pattern, Fig. 172.

The best way to make a strong pattern is as shown in Figs. 172 and 173. The main portion of the body is worked by hand away from the lathe. On this the other portions are fitted

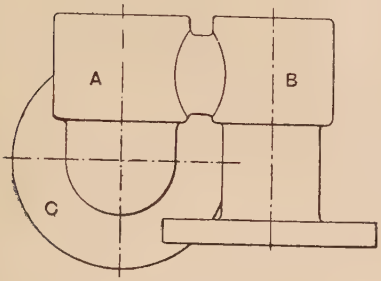


FIG. 169

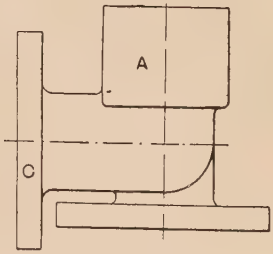


FIG. 170

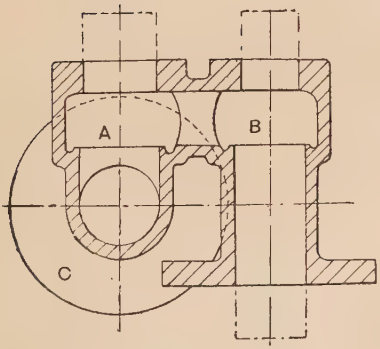


FIG. 171

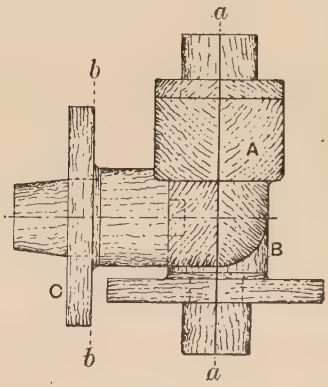


FIG. 172

—boss pieces, and branches, and coreprints. Two alternative methods are shown in Fig. 173 for the latter, one being a dovetail, the other a circular stud. The inlet branch is fitted by a dovetail, the outlet branch with a stud (Fig. 172). The outlet flange in the same figure fits over the print loosely to be left behind in the mould. The core would often be made in two, the portion for the delivery branch being distinct from the main core. But that is not necessary or desirable when many moulds

have to be taken. Fig. 174 with Fig. 175, which last gives a section through *a—a*, Fig. 174, show the corebox for making one complete core. A branch portion is fitted on the back of one-half the main box, being dowelled, and may be also dowelled in halves, or made solidly. There is no difficulty in delivery or in handling the core.

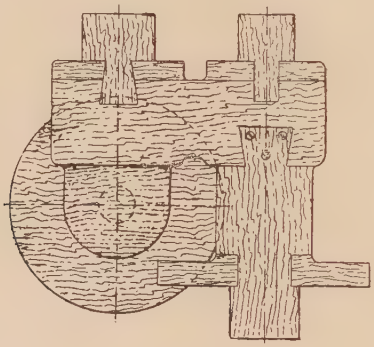


FIG. 173

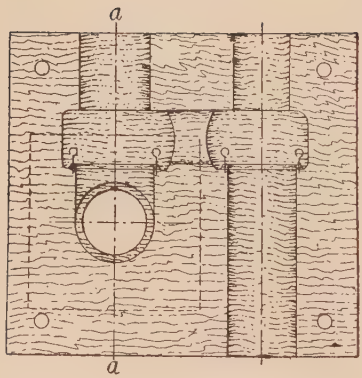


FIG. 174

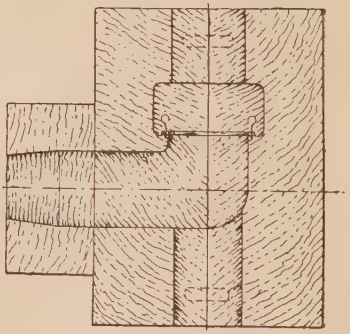


FIG. 175

Bib Cock.—The bib cock, Fig. 176, stocked in small dimensions, with bores ranging from about $\frac{3}{8}$in. to $1\frac{1}{2}$in., is made solidly, and moulded on a joint board, or parted and plated, and is made in hardwood or in metal. The method of constructing a strong wooden pattern is indicated in Figs. 177 and 178. The grain at the bib or nose would be short if cut from the solid. That portion is therefore fitted as a separate piece. The flange and

its print are also fitted as separate pieces. Fig. 178 shows the pattern body as it appears when turned, leaving the curved bib portion to be worked round by hand-tools at the bench. In this figure the globe body is shown as left to be worked at the bench,

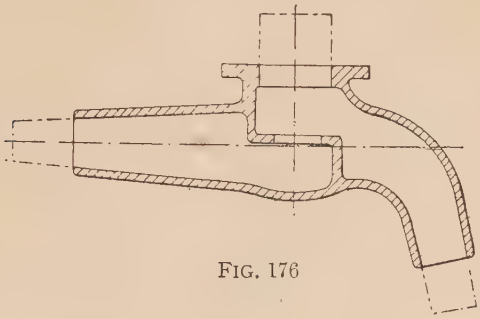


FIG. 176

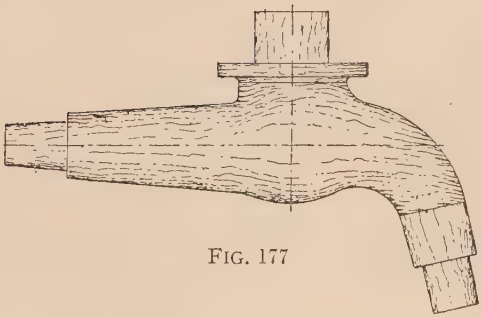


FIG. 177

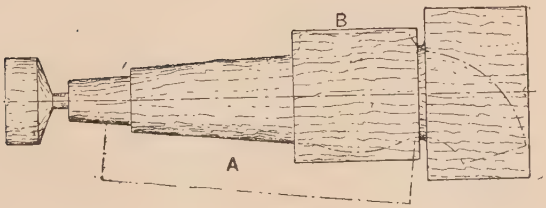


FIG. 178

using a templet outlined at A. But the body might be turned as indicated by the dotted lines, in which case a block would have to be fitted at B to take the flange. Fig. 179 shows one half the corebox made in metal open in its joint face. Note that the taper of the core is continued in the print and box.

A good many patterns have branch pieces which stand out to considerable distances from the main body, and in which, therefore, good jointing must be done if the union is to be permanent.

Safety Valve.—Fig. 180 shows the body of a combined dead-weight safety valve and stop valve. The stop valve goes in the

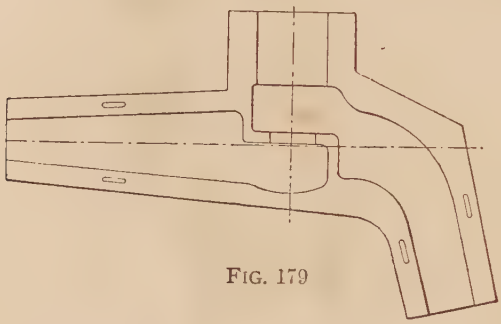


FIG. 179

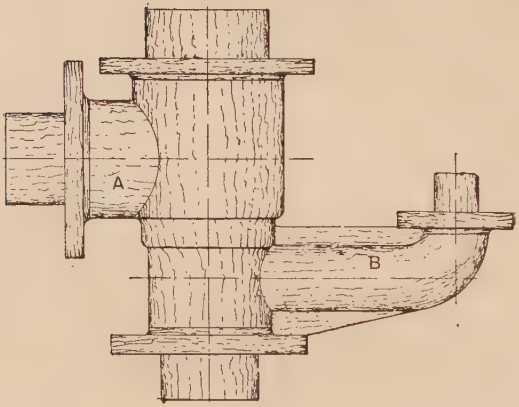


FIG. 180

main portion, and the safety valve is attached to the flange on the branch to the right. Fig. 181 shows one half of the pattern open in the joint, while Fig. 182 is taken at right angles to show further the method of fitting the branches. The main portion is turned complete with flanges let into the grooves, and the branches are fitted to abut against it, being cut to fit the curves of the body. But if nothing more were done except to insert screws or nails, the joint would not be secure. The branch pieces are let

into the body, therefore, and screwed. Taking the inlet branch A first, it is fitted as shown in Figs. 181, 182 and 183, against the curve, and with a tongue in the joint. The tongue must be parallel, as a dovetail cannot be fitted easily unless made and fitted separately into branch and body, as is often done in pipe

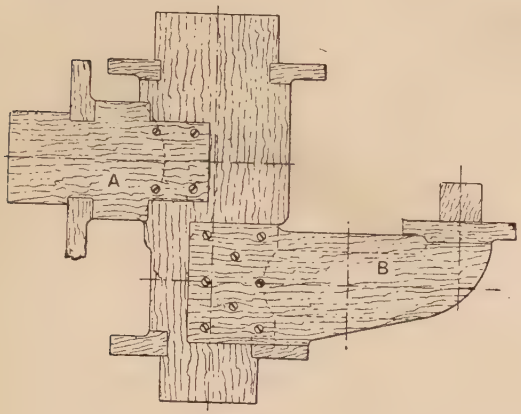


FIG. 181

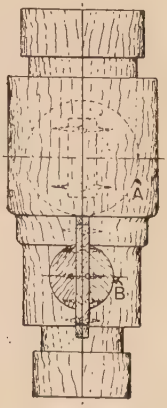


FIG. 182

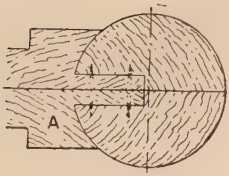


FIG. 183

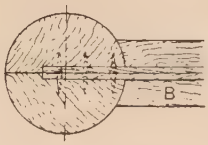


FIG. 184

work. Branch B is strengthened with bracketing in the form of a mid web. This is better fitted apart from the body of the branch in the manner shown in Figs. 181, 182 and 184. Since such a pattern as this would be jointed along the centre, the web is made in two thicknesses (Fig. 184), let into the joint faces and glued and screwed. On this the branch pieces are fitted, being less than the complete circle by the web thickness. A pattern made thus is as strong as one can be constructed in wood.

CHAPTER VII

EXAMPLES OF MOULDS

Globe Valve.—Among the commonest articles seen in the average foundry are globe valves. They occur in a large range

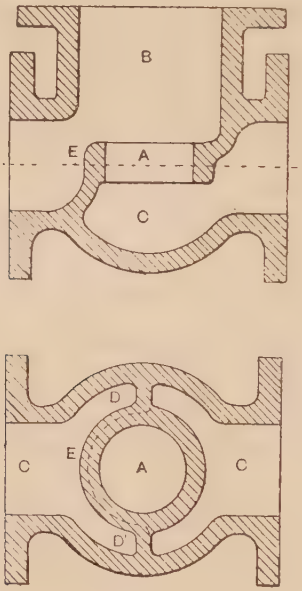
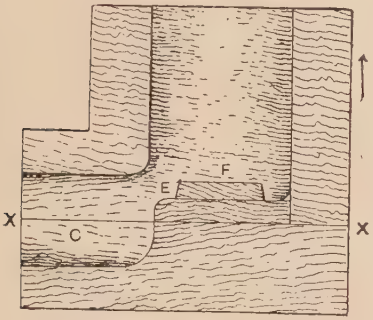


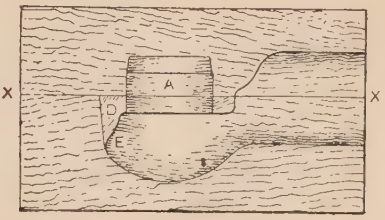
FIG. 185

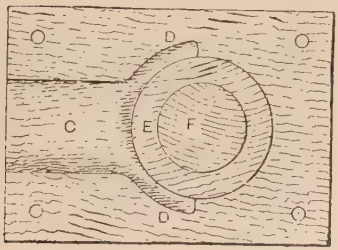
of dimensions, with flanges and with sockets. And akin to the globe valves proper are many others with globular bodies used for specific purposes, but having much in common from the point of view of methods of moulding.

Fig. 185 shows a typical globe valve in vertical and horizontal sections, in which water or steam enters at one end, passes the

valve in the seating A, and escapes at the other end. The seating A forms a diaphragm; hence years ago these were often known as "diaphragm valves." The methods of making them depend to a certain extent on dimensions. Thus, comparing the large valve in Fig. 185 with that in Fig. 189, the conditions are seen to be different with regard to the coring, due to the shape of the core when viewed in plan. In the horizontal section seen below in







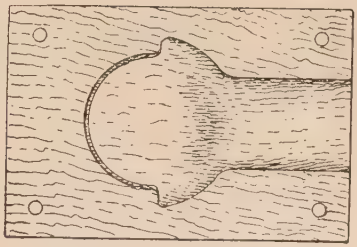


FIG. 186 FIG. 187

Fig. 185 the metal curves round the seating A, leaving a space between this and the outer metal in the body. In Fig. 189 the metal goes straight across. The reason for this difference is the economy in weight in the larger castings. In the first it is clear that the core will not deliver from a box made entire with curved metal round the hole A, because that means undercutting, but that the core can be readily got out of a box in which the metal is not curved, but carried down perpendicularly; and this explains the reason for the difference in the methods of making boxes for large and small valves.

When such patterns are of large dimensions they are moulded singly. Only when of medium or small size are several put in a single flask (*see* Fig. 111). At present we consider moulding a single pattern in a box.

Figs. 186 and 187 illustrate the construction of the core boxes for Fig. 185; and Fig. 188 is a plan view in the joint of the cored-up mould. Comparing these, it is seen that the cores are fitted into one another with a print impression, the print being put

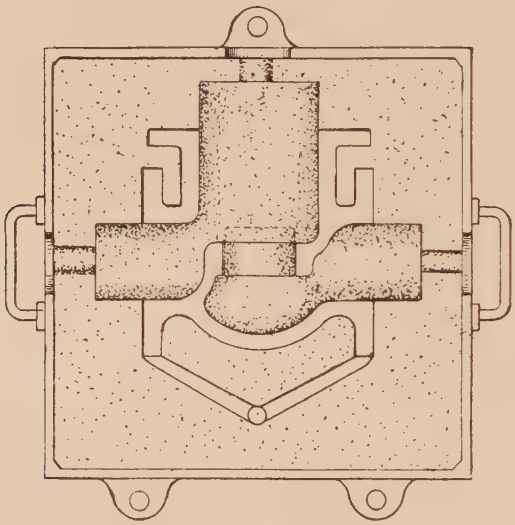


FIG. 188

in one of the boxes, and a recess bored in the other. The drawings of the boxes are nearly self-explanatory. The boxes are made in wood for large valves, in white metal for the small ones. The outlines are marked from the sectional drawings of the casting in Fig. 185, plus allowances for prints, and for boring and facing the valve seating A.

Fig. 186 shows the core box for the part B of the valve in Fig. 185, the upper view being taken in the same vertical plane as the casting, the lower one along the dowelled joint X—X of the box. It is difficult to represent by shading the exact curves at different portions, but a little consideration will show that D, D

are the largest cored parts of the valve, and that the globular form sweeps down from thence to merge into the boss E in one direction, and into the semi-circular hole C in the other, all of which are worked by templets in a manner well understood by patternmakers. The boss E and the print F stand up above the joint level X—X, and are therefore prepared separately, and fastened on there. The shape of the upper part of the box can be seen by the top figure. As this portion has to be taken off the core in the direction of the arrow, a little taper is put in the hole.

The core box for the part C in Fig. 185 is shown in Fig. 187 in the same way as the previous one, the top half being removed in the plan view below. The hole at A in the top is equal in depth to the seating A in Fig. 185, plus the print thickness F in Fig. 186. The box joint X—X, along the centre, involves making the piece D separately from its own proper half, and attaching it to the top half of the box, otherwise the recess E would not deliver. An alternative would be to bring the metal down straight, so increasing its amount slightly.

The cores are stiffened with rods bent round, and with nails, and the air is brought away into the prints. The two cores may be cemented together, or not, according to the way in which the valve is moulded; but the vents in the two should not communicate, but stop short at the joint in the seating A, in order to prevent risk of metal getting into the vents. In the case of a flanged cock like that in Fig. 185, the mould is made as the drawing lies—that is, the joint is in the plane of the paper. But when large cocks are made with sockets, or to be screwed externally, they are sometimes moulded the other way—that is, with the joint perpendicular to the first-named. In the latter case the cores can be laid separately in the mould, B first and C next. When moulded according to the usual method, the cores are cemented together and laid in as one.

Fig. 188 shows a plan view of the cored-up mould of the valve opened in the joint, with the arrangements for casting, as made for a large valve.

Valves of this class can be poured directly on the top edges of the flanges, or against flange faces, or edges, as shown, either

one or two runners being used, according to the size of the valve. The runner, as shown, must be deep in proportion to width to carry the metal freely.

The small valve shown in Fig. 189, with edges A, A, perpendicular, has its core box made as in Fig. 190, shown open in the

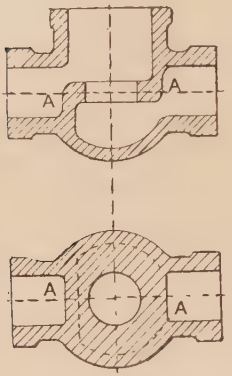


FIG. 189

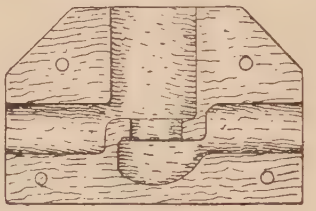


FIG. 190

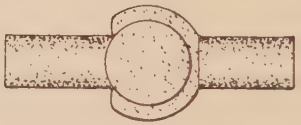


FIG. 191

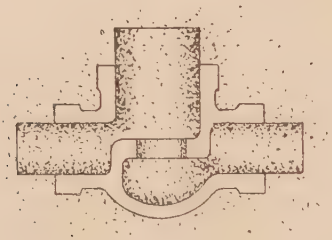


FIG. 192

joint. The core is seen in plan in Fig. 191, and the cored-up mould in Fig. 192.

Jobs of the kind here illustrated are moulded usually by the aid of a bottom board, the pattern being jointed. The board is laid upon the floor or on the bench, the drag half of the moulding box set on it, the half pattern that has the dowel holes set within in its suitable position, and rammed. The board, box and pattern are turned over, the board removed, the other half pattern set on the part rammed, and the top part of the box fitted and

rammed. The gates are cut after the boxes are separated. There is no economy of time possible in such work when a few castings only are ordered at a time.

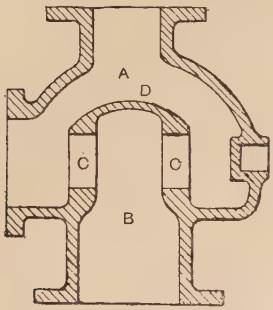


FIG. 193

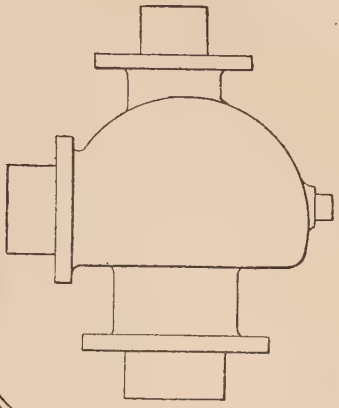


FIG. 194

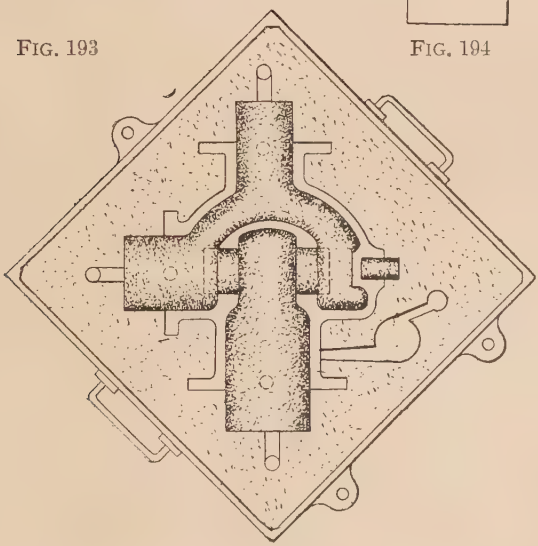


FIG. 195

Equilibrium Stop Valve.—Fig. 193 shows the shell of an equilibrium stop valve. The two main cores, A and B, are made separately. Core recesses are formed in A, into which the cores C, C, on B are fitted. The core A, therefore, is made in halves. An alternative way would be to let the edge D go down perpen-

dicularly, and make the core all in one from one box, a half-box or a dowelled complete box being used. This method is suitable for the smaller valves.

The pattern is shown in Fig. 194; a plan view of the mould in the joint face, cored up, in Fig. 195; and a plan view on the top box, showing the pouring arrangement in Fig. 196. The cores are vented into a central channel, or each half core might be vented separately. As the pattern is most conveniently arranged diagonally in its flask, the air cannot be brought away in

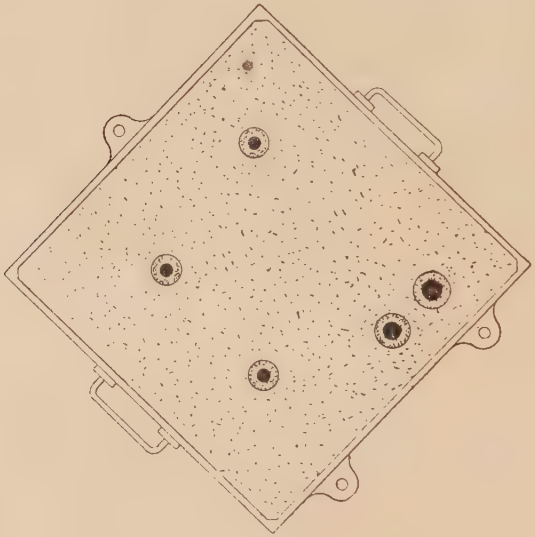


FIG. 196

a straight course, but it is carried down to the bottom of the bottom box in the manner shown in Fig. 197. A piece of rope is rammed in the mould next the end of each core print, and carried down to the bottom, whence it is easily drawn out, leaving a vent channel E for the gases—a device often adopted in jobbing work in which similar conditions exist.

In the equilibrium valve shown in Fig. 198, with a midfeather, the method of construction is similar to that in Fig. 193, except that the midfeather is put in the joint of the core box, being fitted and retained in rebates cut in the joint face of the

box. Another globular valve of the flap type, shown in Fig. 199, has its core made in one box only, everything delivering freely.

Large patterns of valves like these are usually jointed. When made solid, the top part of the moulding box has to be lifted off the bottom one and away from those parts of the pattern which stand up in the top. To lift the top from a pattern without fracturing the sand is more difficult than to withdraw a pattern from a mould. Top prints have more taper than bottom ones

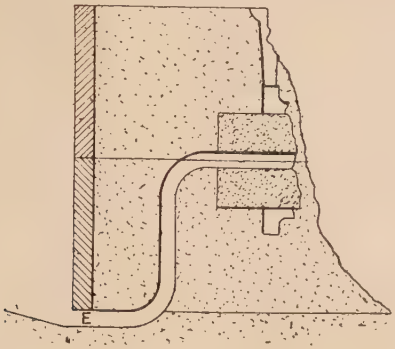


FIG. 197

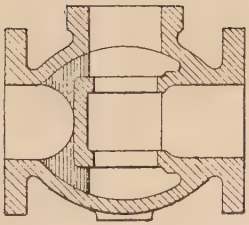


FIG. 198

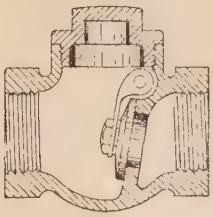


FIG. 199

because of this difficulty, and in certain cases the upper portions of patterns are tapered more than the lower parts. Where deep flanges stand up like those in Figs. 194 and 198, little can be done in this way, and the top sand is liable to fracture against their faces. As it is not possible to rap the patterns in the top as they are rapped in the bottom, the following devices are resorted to.

In the case of some of the heavier patterns, a rapping bar is inserted, being thrust down through the top part into the pattern,

and rapped. This is rather unusual, though serviceable in some instances, particularly when edges are deep and nearly vertical. Another way is to lay a board upon the top of the box, and rap that with a wooden mallet, and also to rap the sides of the flask on opposite sides alternately. This has to be done with moderation only, or a risk of a drop-out would occur. On lifting the top part of the flask, if any serious fracture is found to have

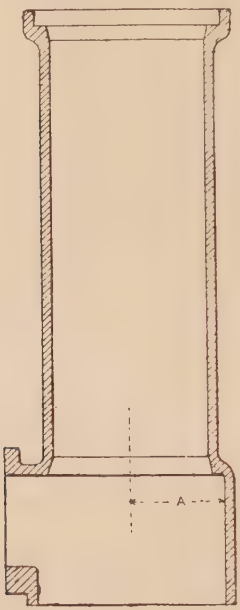


FIG. 200

FIG. 201

occurred, the broken part is moistened with clay water, and the top part returned, when the fractured portion may be re-moulded. Or the pattern can be lifted out of the bottom part and put back in the top, and the sand made good with the fingers or with suitable small tools. The same method of replacing the patterns is adopted when any part of the bottom mould breaks up. The patterns are lifted out from this by the fingers, or by the spike in the case of wooden patterns.

Pump Barrel.—Pump barrels, and pump liners for cast iron barrels are made in brass. A barrel may be perfectly plain,

bolted between suction and delivery boxes, or it may contain a doorway to permit of examination of the suction valves, as in Fig. 200. There is no difference in the method of moulding adopted in the case of liners or barrels, but some differences in the details of the cored work. Such castings are generally poured horizontally instead of vertically, which would be the better way to adopt

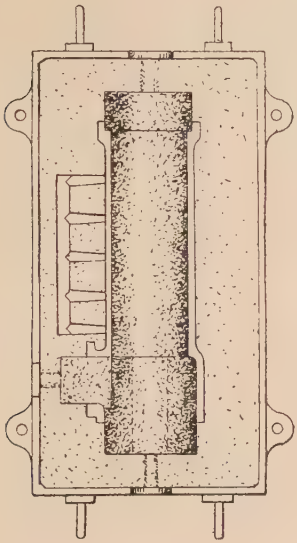


FIG. 202

FIG. 203

in the case of cast iron. The following description applies generally to all work of this class, but specially to the barrel in Fig. 200. The ends are not flanged, but are checked into recesses turned in the suction and delivery boxes.

No observations need be made on the pattern, which is shown in Fig. 201, constructed by one particular method among several. With regard to the cores, when pumps are manufactured in large numbers it is better to make the cylindrical core which forms the bore and the D-shaped portion at the lower end in one, from one box. But this would no longer be classed as jobbing work, for which the usual method is to sweep the main core up against the edge of a board, and make the D-shaped portion separately. A core box is required for this part. The core may be made to

slide over an extension of the swept-up core, shouldered down as a pin in the manner shown in Fig. 202, which is a plan of the cored-up mould. Or it may fit bodily against an extension of the main core, enlarged to the radius A in Fig. 200, as shown in Fig. 203. There is little, if anything, to choose between the two, and both methods are adopted to about an equal extent.

The pouring of barrels or liners is done either from the ends or from the sides. If the metal at the ends is massive, as

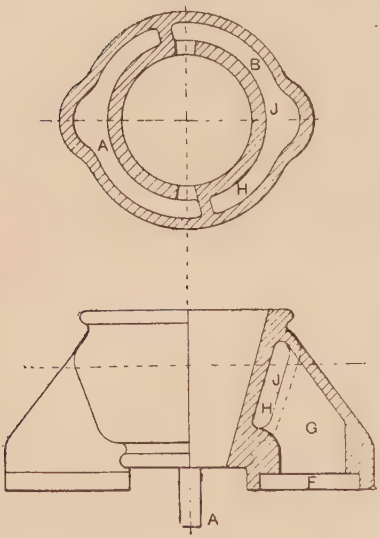


FIG. 204

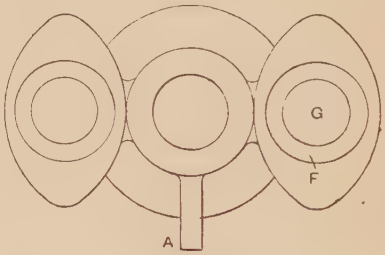


FIG. 205

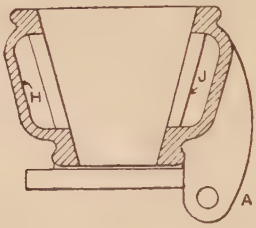


FIG. 206

when liners are cast with thick belts there, or when barrels are flanged, this affords a good opportunity of pouring at one end, and the metal takes a clear passage between the core and the mould. In the type shown, a spray of runners at one side, as seen in Fig. 202, is better. These fill the mould up quickly down a great portion of its length at once.

Valve Casing.—A neat piece of cored brasswork is the valve casing shown in Figs. 204 to 206, of which a large number have been made in the way to be described. It forms a steam and exhaust valve alternately for an oscillating cylinder, the trunnion

of which is cast on the cylinder. This particular type of engine is used for warehouse hoists attached to walls.

The trunnion has passage-ways cast in it which are separated by a mid-feather. As the cylinder oscillates against the fixed valve these ports are alternately presented to the ports in the valve, and each of the latter becomes in turn a passage for steam and for exhaust. As there is no early cut-off, this would be too wasteful a design for continuous service.

There is not much involved in the work of the pattern, but

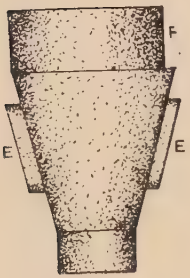


FIG. 207

FIG. 208

the chief interest centres in the cores and their boxes. The centre core is simple. Some trouble is given by the flanking passage cores, not in the making, but in the setting. Looking at the sectional view in the upper part of Fig. 204, it is seen that these cores, which form the passages A and B, must be so set that the metal between shall come in a particular position, otherwise the steam will not be cut off at the correct point. Yet no support in the shape of prints can be afforded to the cores at this section. They have to be carried wholly by their circular ends in the print impressions at the flange faces, and chaplets only can be used at the other. The correspondencies, therefore, of the pattern and

core boxes with their prints have to be attended to carefully, and the cores have to be set in their mutual relations chiefly by the assistance of the eye.

Views of the two separate cores, and of the mould, cored-up, are shown in Figs. 207, 208, and 211 to 213.

Fig. 207 is the body core. The two passages E, E are rammed in this core in one box. As a guide to setting them in the mould, so that the passages will come exactly plumb, a flat is cut on the print, and a piece put in the box, leaving a flat F in the core. When these flats correspond in the mould the core is in its right position, with the passages plumb in the mould. (Compare with Fig. 213, in which the mould is seen in vertical section.)

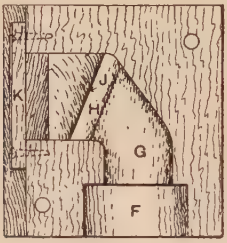


FIG. 209

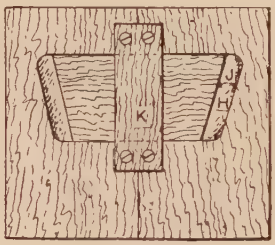


FIG. 210

One of the flanking cores for steam or exhaust is seen in Fig. 208. Both these cores can be made from a single box (Figs. 209 and 210), with reversal of the angle of the face. (Compare with the sectional view in the upper part of Fig. 204.) This reversal is easily done without cutting the box by simply screwing temporary pieces on the faces to give the angles.

Of the two views of the box in Figs. 209 and 210, the first shows one half opened in its joint face, and the second shows the complete box as seen at the joint face. Comparing these with Fig. 204, the part F takes out the seating for the gland, plus the necessary length of print by which alone the core can be sustained; the part G forms the passage, and the concave face H corresponds with H in Fig. 204, which gives the metal round the valve body. The metal J round the hole which is cored for the trunnion is given by the edge J of the loose block which lies concentric with H, and which is kept in place by means of a batten K screwed

temporarily to the sloping face of the box, the slope of which corresponds with the angle of the separating metal in the upper view in Fig. 204.

As these cores have to be inserted after the main one D in

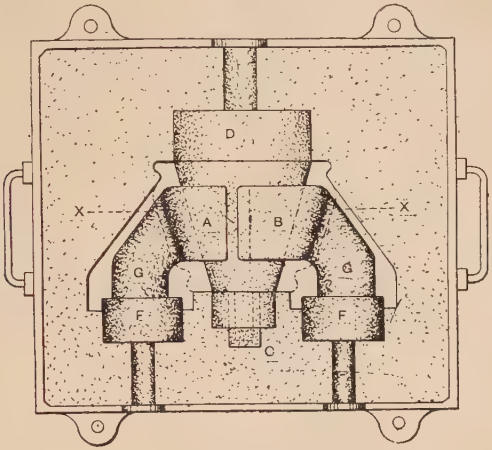


FIG. 211

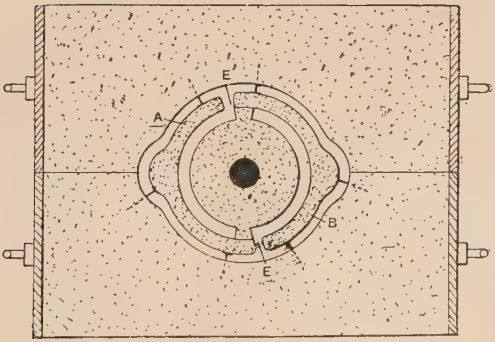


FIG. 212

Fig. 211, they must be rotated in their print impressions in order to slide them round the main one. Before either is put in, a chaplet or two, made of brass, will have been thrust into the bottom and sides of the mould for the cores to rest on, and to ensure the thickness being right there. When the cores are lowered in, their position with reference to the passages E, E in the

middle core (Fig. 207) can be seen. The thickness of metal in the top is checked by a plug of clay, and the cores are prevented from rising by chaplets in the top. The relative positions of

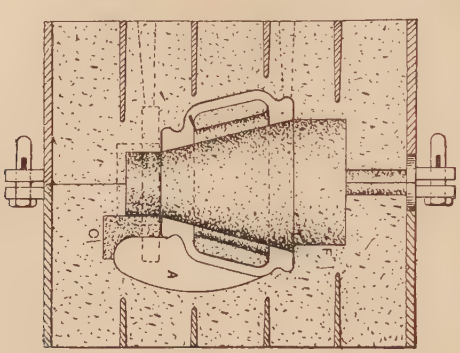


FIG. 213

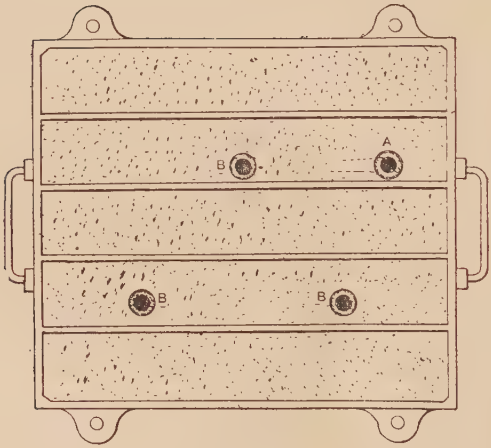


FIG. 214

these cores in the open mould are seen in Fig. 211. Fig. 212 shows the cores in section, taken in the plane X—X in the previous figure. Fig. 213 is a vertical section through the mould taken at the centre.

There is a lug shown at A in Figs. 204 to 206 by which the valve body is attached to the cheek of the hoist. As it stands out beyond the face of the body, this portion is cored over in preference to leaving it loose. This is shown at C in the view Fig. 211, and also in Fig. 213. The core print was brought to the joint of the pattern, and the core stopped over. It is thicker than the lug—a feature which is favourable to delivery.

A plan view of the pouring arrangements is seen in Fig. 214, in which A is the runner, and B, B, B risers over the heavy flanged parts.

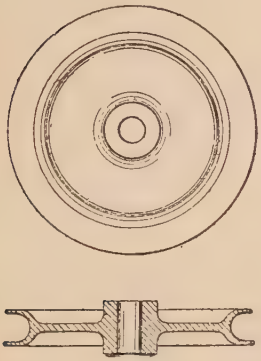


FIG. 215

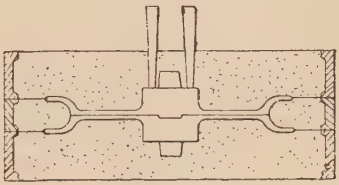


FIG. 216

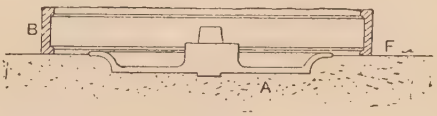


FIG. 217

Sheave Wheel.—Large numbers of sheave wheels (Fig. 215) are cast in brass, and the methods of making them differ. In the case of those of large dimensions, usually made in cast iron, the general plan adopted is to use a three-part box. But this would not pay in small castings, for which a common two-parted box must be employed.

Work of this kind, involving a middle ring of sand fitted by two joint faces to the other parts of the mould, and having dished outer faces, is rather expensive if made by jobbing methods. It is a class of work for which a few dozen castings only, pay for some rig-up in the way of bottom boards. This can be done in more than one way.

Fig. 216 shows the mould of a sheave wheel in section, when made in a three-part box. The pattern is seen as rammed in place, immediately previous to parting. Only in the case of

large sheaves should this plan be followed, and as few of large size are ever cast in brass, the illustration is to be taken chiefly as affording a comparison with the methods shown in subsequent figures, rather than as one for general adoption.

This is an example, too, of a class of work which does not afford a flat face for bedding at once on a plain joint board, or on a sand bed. It either has to be bedded into the sand, before the first face can be rammed, or a joint board has to be specially prepared to receive it.

In ordinary jobbing work a mould like Fig. 216 would be commenced as in Fig. 217. One-half the pattern is bedded into loosely-rammed sand A, which is often that of the floor only, or

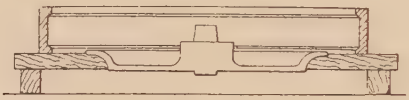


FIG. 218

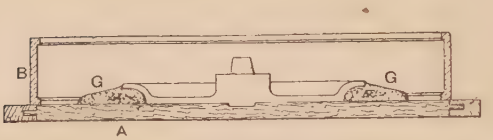


FIG. 219

it may be contained in the box part that matches the part B, which last will be the drag when turned over, and the mould completed. B is rammed solidly and properly and vented, and turned over with the half-pattern in it, upon which the other half-pattern will be placed, and the middle part then rammed, and afterwards the top part. These successive stages are substantially illustrated in subsequent figures, but with the omission of a middle part box.

Looking again at Fig. 217, it is obvious that some time must be occupied in doing work for which no permanent result remains. The sand bed A has to be scooped out, the pattern bedded in, taken out, and reinserted two or three times by way of trial; and the joint face F must be sleeked level with the centre of the rim, which work is absolutely thrown away so far

as the permanent mould is concerned. To avoid this it pays, if only a few castings—say, two or three dozen—are wanted, to recess a joint board (Fig. 218) to ram the drag part on.

We now follow out these methods in the case of the sheave wheel moulded in a two-part box. The device adopted is shown in Fig. 221, the middle zone of sand which forms the cupped portion of the sheave being formed as a loose ring, jointed by sloping outer faces to the sand in the top and bottom boxes. The ring of sand is of course stiffened with a hoop or hoops of iron rod.

Here the work of jointing would occupy more time than in the previous instance (Figs. 216 and 217), because the joint is

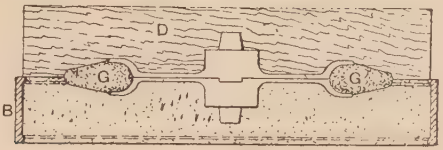


FIG. 220

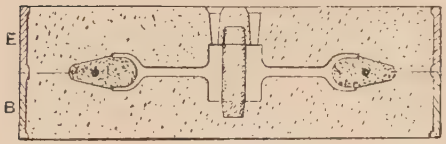


FIG. 221

not flat, but sloping. This might be made in two ways by hand. The half-pattern might be bedded in similarly to Fig. 217, the box B turned over with the pattern, and the sloping joint then made by scraping and sleeking. Or the pattern might be laid on a plain board A, as in Fig. 219, a temporary body of sand rammed as at G, using the hands and trowel for shaping the joint, and the drag be rammed thereon at the same time as on the body of the pattern. But the sand is best strickled off in the manner shown in a subsequent illustration (Fig. 220), with a strickle like D, without the assistance of which some time would be wasted in sleeking an even joint by means of the trowel.

In the illustration Fig. 219 a better plan also may be embodied. The ring G—G may be of wood, lying on the bottom

board, turned to the slope of the joint, and to make a fit with the pattern—a permanent job, which would remain good for many hundreds of wheels.

After the drag or bottom part B is turned over, as in Fig. 220, the second half of the pattern is put in place, and the middle zone of sand G is rammed. This is carried in any convenient way. If heavy, a light cast ring with eyes is used to lift the core by. If light, it is sufficient to ram a couple of rings of $\frac{1}{4}$in. or $\frac{3}{8}$in. rod in the core, and lift the latter in the hands by the outside.

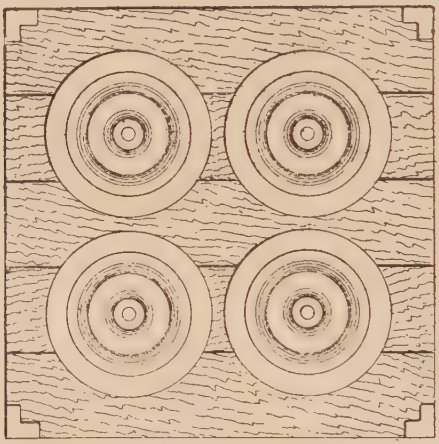


FIG. 222

The top joint of the ring core, which slopes like the bottom one, is most easily made with a strickle D, which is fitted to, and takes its bearing on the top face of the pattern, and being swept round strikes off the top joint of the sand core G. This is done quickly, and makes a true joint face, upon which, strewn rather thickly with parting sand, the top part E is rammed as in Fig. 221, which shows the mould complete ready for pouring. The centre core is seen inserted, with the runner and riser on the boss, which is the best way to pour all wheels of this kind, and many others besides, because the metal does not get chilled, as it might do if poured into the rim or plate, whence it would have to run to the boss. The vents are taken off the faces of

the sheave at top and bottom, and the vents of the core ring come out at the joint of the mould.

It might be thought that the rim would be more easily taken out with a dried sand core than with green sand. But it is not usual to do so. In some cases rims are cored out. There would be advantage in this plan if four sheaves were arranged on a plate as in Fig. 222. The core box should then be made as in Fig. 223. A bottom board A is recessed to take a piece B, in which one half of the rim is turned, and on which a piece C is studded, forming the other half of the rim. The lower half of

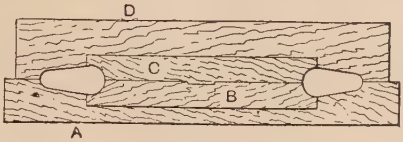


FIG. 223

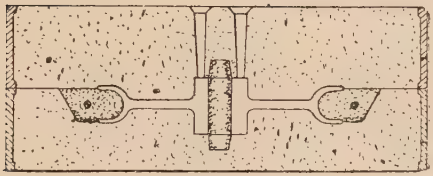


FIG. 224

the joint is formed in A; the upper half is swept round with the strickle D. B and C are made thick at the edges to preserve them.

There is yet another way of jointing sheave wheel moulds, shown in Fig. 224. Instead of setting the centre of the wheel in the same plane as the joint of the boxes, the centre of one flange is so placed. The rim core is thus brought entirely into the bottom part (or the top) and checked into the box sand with a well-sloped joint. There is rather less trouble involved than in Fig. 221. Either of the methods of moulding here described may be applied to Fig. 224, joints being made by hand-sleeking or swept by templet, or a joint board can be used. The ring can be made in a core. The writer thinks it is the cheapest way to mould small sheave wheels in quantity.

Economical Arrangements.—The groups of figures next shown illustrate several points of value in the work of the brass foundry.

A good proportion of the work done in most brass foundries consists of outdoor orders, which come from private individuals and from firms, and which may or may not be repeated. For these no special rig-up is as a rule economical, but the work is moulded by turning over on joint boards. In such a miscellaneous class it is often difficult to arrange some of it in the most economical manner. For instance, a pump or a safety valve will have one main body in brass, and several smaller pieces. Among the latter there may be two or three valves of one size, or glands, spindles, nuts, either of one size or nearly so. The larger piece will not always lend itself to specially economical methods of manufacture. Often it has to be moulded alone in a flask by itself. The small parts, on the contrary, may be arranged together, either by themselves or along with others of a similar character belonging to other orders, either loosely in a box by the common turn-over method, or on an odd-side. Here the judgment of the foreman comes in, to so distribute the various pieces that all will be done in the manner which on the whole works out at the lowest cost, and which will give the right numbers of castings, both large and small, without any being in excess, or any moulding boxes being only partially occupied. A set or sets of work, therefore, would not generally be handed over to one man, but would be divided and distributed along with other sets among men and youths.

This of course raises the question of joint boards of various kinds, of plated work, or of odd-sides. The plain bottom boards do good service. But for their indiscriminate use it is necessary that the patterns have one plain face, or one plain joint, to be laid upon the board. As soon as irregular outlines come in, or irregular joints, if joint boards are used for such they become special and more or less expensive; and then it may in many instances be difficult to decide between moulding by hand methods or by the assistance of such boards, or whether to use odd-sides.

Valve Stems.—The valve stem, Fig. 225, can be moulded along with small hand wheels in the manner shown in Fig. 226. This affords an illustration of economy in box filling. The hand wheels have no manner of relation to safety valve work. But the stems

arranged as in the figure leave great waste spaces between the stem portions, and the hand wheels just fit in nicely here. If both happened to be standard work, the patterns might be put permanently on a plate of wood or metal. If for jobbing work, an odd-side could be made. But neither of these can be rammed on

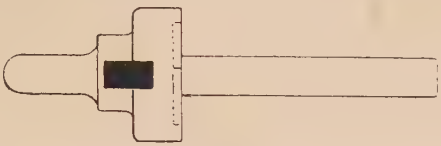


FIG. 225

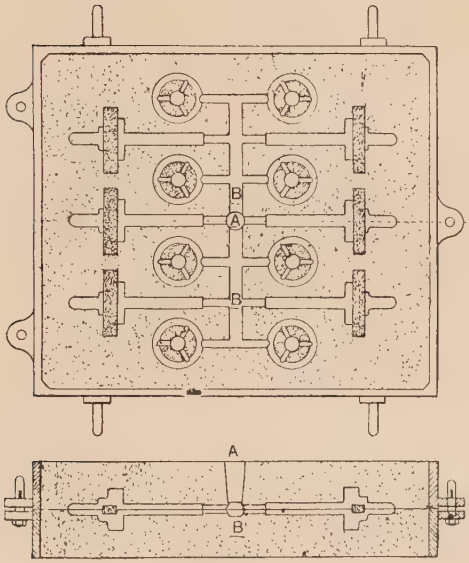


FIG. 226

a plain bottom board, and the alternative to odd-side would be moulding by ordinary methods—bedding in the patterns first and making the joint face, then ramming the drag, turning it over, and ramming the cope. Or another way would be to ram the patterns alternately, as in Fig. 227, which would answer just as well. In this case, too, some small patterns might be cast next the ridge runner, small neck bushes being illustrated, but nearly anything of small dimensions might be used for filling in.

The mould shown by Fig. 226 is poured flatwise, A being the ingate, and B the ridge, feeding the separate runners. The cores in the stems are laid flatwise in the mould, rather than perpendicularly. No centre cores are put in the hand wheels. It is better to omit them in small wheels and drill through solid clean metal.

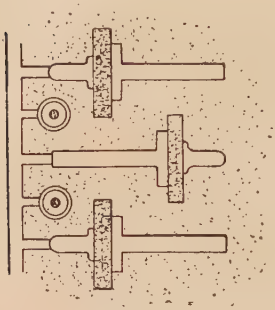
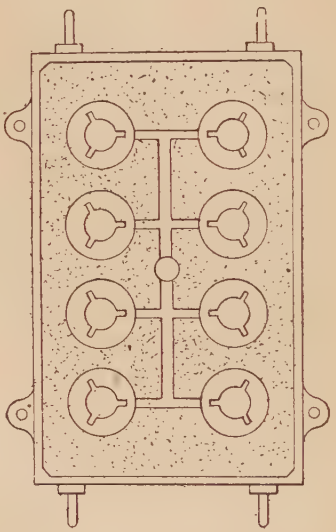


FIG. 227



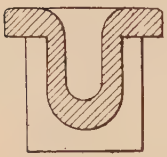


FIG. 228

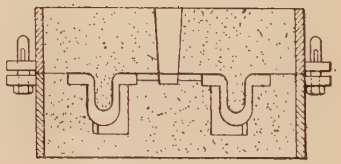


FIG. 229

Safety Valves.—The moulding of the safety valve in Fig. 228 is shown in Fig. 229, eight valves being arranged in a 14in. by 9in. box. The plan view above shows the bottom box open after the moulding is complete and the patterns drawn; and the lower figure is a section through a couple of valve moulds. This also is poured flatwise, and the arrangement of runners is similar to the last. Further references will be made to this figure presently.

The next group of figures (230 to 237) shows four different classes of safety valves being moulded in one flask, a good

FIG. 230

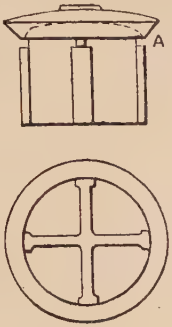


FIG. 231

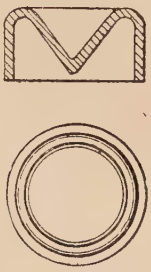


FIG. 232

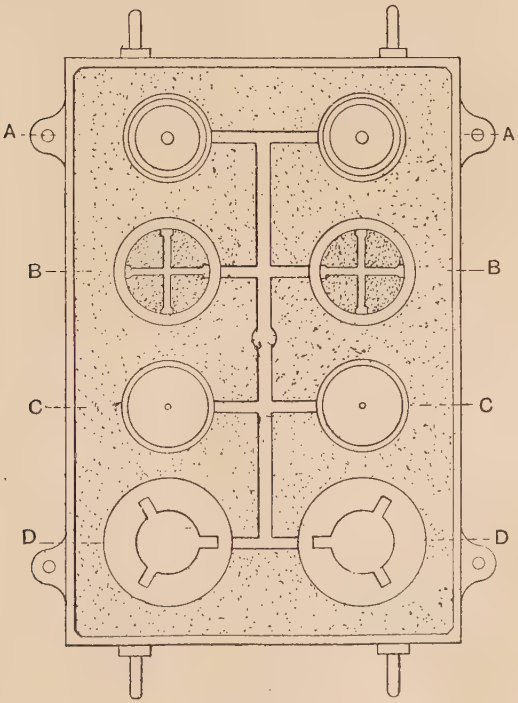


FIG. 233

arrangement for jobbing or for standard work, because there is not much difference in sizes. Three types of valves are seen in

Figs. 230 to 232, the fourth valve is the same as Fig. 228; Fig. 233 shows the bottom part of the mould open; Fig. 234 the top part removed and turned over face upwards. Cross-sections are shown in Figs. 235 to 237, that through D—D in Fig. 233 being the same as in the section in Fig. 229.

Looking at these sections, the jointing of the mould is seen to coincide with the largest diameter, whence tapers go up and

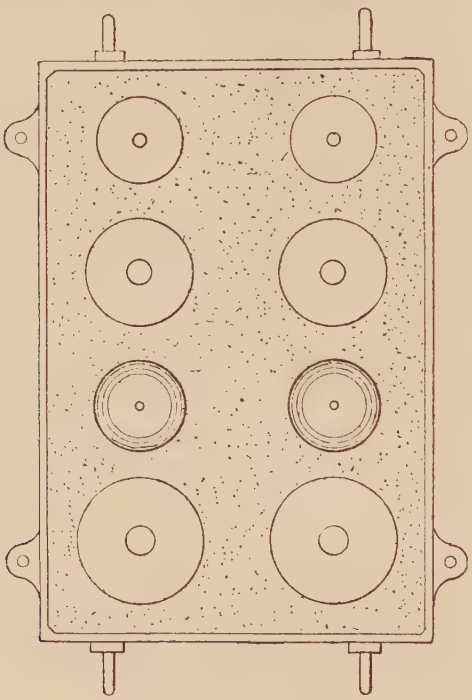


FIG. 234

down, and the valve faces are cast downwards. The joint face is flat, but the patterns are not, and therefore these are moulded by turning over in the ordinary way without a bottom board. Special boards could be made and recessed to receive the patterns, but then that would not be jobbing work.

Comparing Fig. 231 with the section of its mould, Fig. 236, two points are noted. One is the extension of the stem in the casting, which is done to afford a chucking piece for holding the

valve during turning. The other is that no attempt is made to cast the recess at A, Fig. 231, because that would interfere with drawing. The pattern is made continuous, and the recess is turned out in the casting.

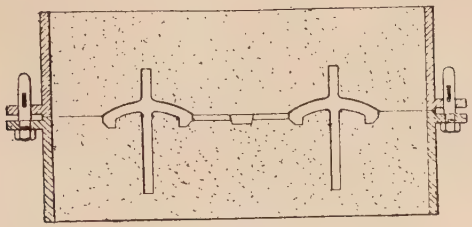


FIG. 235

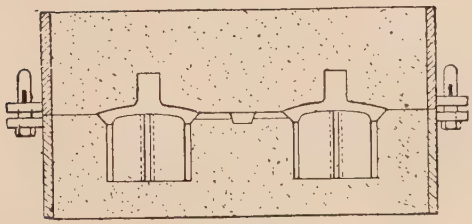


FIG. 236

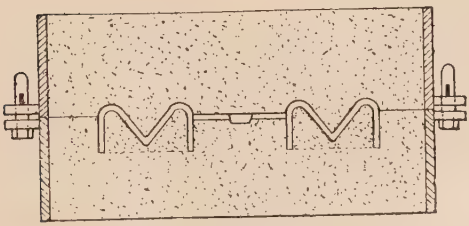


FIG. 237

When arranging several patterns in a flask, sufficient sand must be left between those parts which come into closest contiguity, to withstand the pressure of the metal. How much to allow depends on the pressure of the metal. In the lower portions more sand must be left than in the higher—more where the metal is massed heavily than in thin portions. In shallow work subject

to little pressure, as little as $\frac{1}{2}$in. of sand may suffice; in the contrary conditions, 1in. or even more will be necessary. Suitable quantities of sand are shown in Figs. 226, 229 and 233.

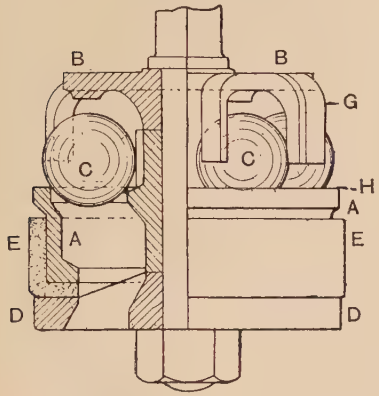
There is a good deal of work about which there is initial difficulty in respect to the best method of making—whether to use cores or allow the parts to deliver themselves. In many, perhaps in most, cases there is no doubt about the matter. There is either no alternative, or no difficulty in deciding which is best. Coring is of value in some deep lifts, or else to avoid loose pieces or false cores, or extra joints in the mould, or to get cleaner and truer faces or smoother outlines in some cases. Small cores cost little in the coreroom, but they have to be fixed with care. The principal objection to their use is that attendant on venting them and bringing off the air. Not that there is any special difficulty in this, but in careless hands it causes more risk of bad castings than is incidental to moulding without cores. The more cores there are, the more involved the task, because the risk of air getting into the vents is increased, and there are more parts to secure.

The six valve stems in Fig. 226 have their holes cored, because it is the only practical way. The reason why the patterns are laid so that the cores will come horizontally instead of vertically is that in the latter arrangement the top would be more liable to crush over the cores than in the method shown. In Fig. 229 the deep recess in the top of each valve might be thought a case for coring on account of the depth there, which has to be lifted with the top. But it would be a mistake to core, for the hole is really more favourable to self-delivery than some shallower ones would be. The bottom is of semi-circular shape, and the sand will not stick there as it will in a hole terminating in a keen angle. The top edge is well rounded, which is also favourable to delivery. A very little taper in the sides of the hole will then suffice. The sand is rather weak, but it can be nailed securely.

Pump Parts.—Some examples of pump details which illustrate further the remarks just made on jobbing work, and on coring and self-delivery, are here given.

Fig. 238 shows a complete bucket as used in the barrels of some 5in. pumps. It comprises the body A, the cover B (with horns, between which as seatings the valves C are retained), and

the guard ring D confining the leather E. The details are clearly shown by the comparison of both figures, the upper one being a half-elevation to the right and half-section to the left; the lower one being a plan to the left, and a plan on the line H to the right. A and D must be cored out; there is no alternative which



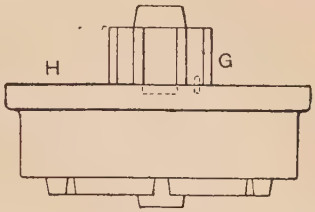


FIG. 239

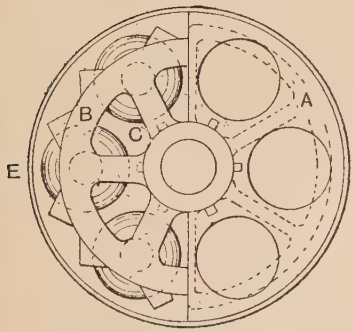


FIG. 238

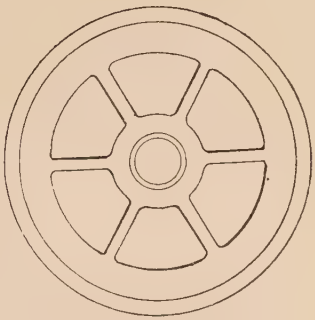


FIG. 240

is practicable. B delivers itself. The best way to mould these is in square boxes, four in a box; and there is no advantage in mixing the patterns for different pieces in one box.

Taking the main body A first, Fig. 239 shows its pattern in side view, and Fig. 240 the same in inverted plan, to illustrate the core prints. The pattern is quite plain, and the only piece left loose is the boss G, which comes in the top of the mould, and which is retained in place with a central stud. It is as well

to mention, by the way, that when a loose piece can be held with one central stud or dowel it is always better to adopt that

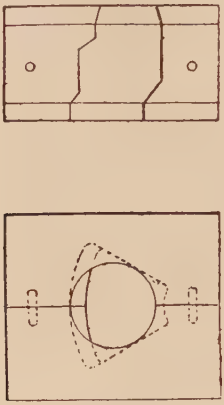


FIG. 241

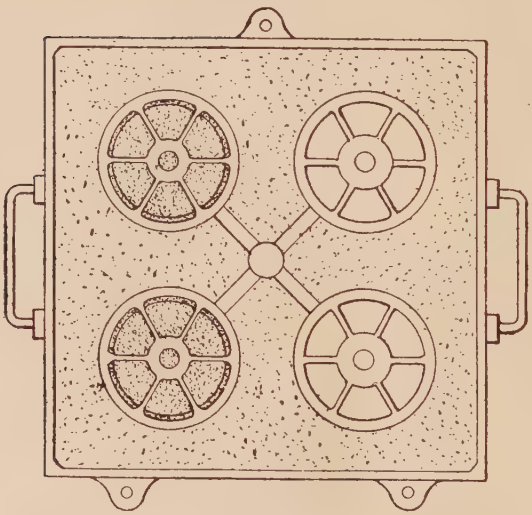


FIG. 242

method than to use two dowels of equal size. In the latter case a mark is usually made to indicate the position of the loose piece, and so prevent error in setting. But a central stud is better, and when a piece must not be allowed to turn round, as in this

instance, because of the position of the shallow ribs on G which serve as guides to the ball valves, that can be prevented by putting in a small dowel to one side of the central stud, as in Fig. 239.

As the top boss G is left loose, the patterns can be laid on a joint board by the face H, which is left quite flat on the temporary removal of the boss. The entire pattern minus the boss is rammed in the bottom box, and the latter turned over, the boss G placed in position, and the top rammed.

The core box is shown in Fig. 241, in plan below and open

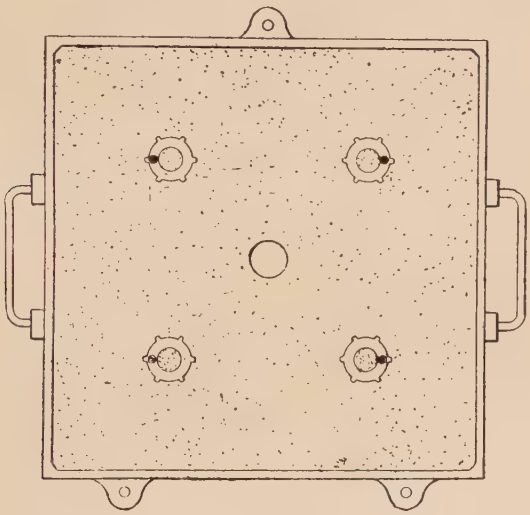


FIG. 243

in the joint face above. It cores out six spaces, nearly triangular in form, separated by ribs, and it cores six circular seatings, upon which the valves drop to close the waterways (compare with Fig. 238).

Fig. 242 shows the bottom moulding box open in plan, with two valve moulds to the right, as they appear on the withdrawal of the pattern, showing the print impressions; and two to the left when cored up. Fig. 243 is a plan view of the top part of the mould inverted.

The pouring is shown going through a central runner, feeding four broad ingates, which is the readiest method. But another good plan would be to fill each mould separately, pouring on

top of the central boss into the thickest body of metal, in which case the runner would act as a feeding head. Pouring in the manner shown, it is as well to put a riser on each boss, as in Fig. 243.

The pattern of the ring D in Fig. 238 is seen in Fig. 244. The core prints are shown on the flat face, which is the proper way. If put on the sloping face they would take longer in fitting, with no corresponding advantage. The slope of the cores to suit that face is put in the core box, in the manner shown in Fig. 245.

In these and other drawings the patternmaker and moulder will notice little details well understood, to which reference need

FIG. 244

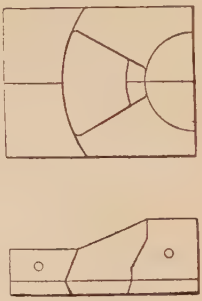


FIG. 245

scarcely be made. Thus, in the core boxes in Figs. 241 and 245 the taper of the prints is put in the boxes, to prevent the moulder from rubbing the cores. The print thickness in the box is therefore conveniently cut distinct from the body. So also is the thickness of the circular valve seating in Fig. 241. Whether made in wood or metal these details should be followed, as saving time and conducing to accuracy. So, too, note may be made of the use of two prints for the central core in the deep pattern, Fig. 239, and of the single or bottom print only in the shallow pattern, Fig. 244. The prints also in both figures, which carry the cores made from the boxes, Figs. 241 and 245, are shallow, because there is no risk of those broad and relatively shallow cores being set out of perpendicular, as there is with a small round core.

The bottom half of the mould made from the patterns in Fig.

244 is shown in Fig. 246, to the right without the cores, to the left cored up. It is best poured with a central ingate and four runners. The alternative of pouring at the boss need not be entertained, as there is a good body of metal in the rim.

There is no coring about B, Fig. 238. The pattern is rather a delicate one to make on account of the slender horns which form the guides for the ball valves. It is turned out first as a solid pattern to the main outlines, and then the horns are marked

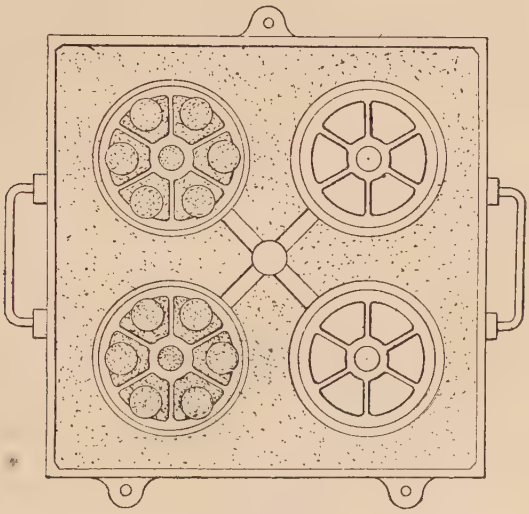


FIG. 246

and cut to shape with gouge and chisel, leaving allowances for turning, for double shrinkage, and for turning a metal pattern. The mould is jointed at G. The pouring is done as in the other instances.

Fig. 247 shows the suction and head valves, comprising three patterns, the seating A, the lift valve B (which is faced with indiarubber), and the guard C (which by the interposition of a spring regulates the amount of lift of the valve). The spring fits into a recess on the underside and the guard is screwed into A with a spanner, for which purpose its head is formed of hexagon shape. The piece A, though rather deep, delivers without coring. D, D represent ribs, of which there are six, and these

in the pattern are let into the turned ring at one end, and into the turned central boss at the other, in shallow grooves about $\frac{1}{16}$in. deep. The wooden pattern may be used, or metal ones cast therefrom, depending mainly on the number wanted off. The methods of pouring illustrated in the previous examples are

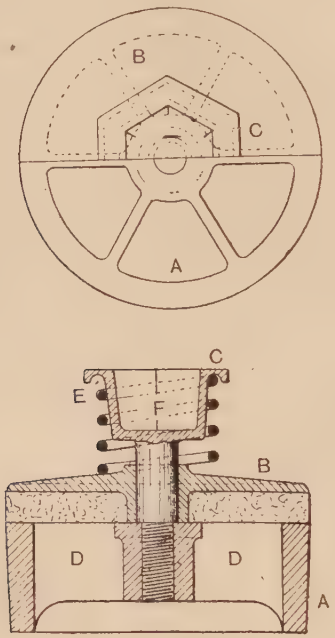


FIG. 247

suitable for this. No hole is cored in the boss, and pouring can be done there or at the rim. The valve B is shallow and plain, and is similarly moulded.

The piece C requires a little consideration. It cannot be moulded on its side, because of the undercutting at E and of the recess at F. Of course it would be possible to core these parts, but it would be very injudicious to do so. The patterns, therefore, must be made exactly like the castings, plus allowances for tooling. The moulding must be done vertically, and each part will then deliver freely. It would be better from one point of view to pour the shank downwards, because that has to be

turned and screwed. But for freedom of pouring, the other way is better—to have the shank uppermost and pour directly into the largest body of metal. It can be left $\frac{1}{4}$in. or $\frac{3}{8}$in. longer to be turned off in case the metal should be a bit dirty next the runner. Several pieces can be arranged in one box and poured from a ridge.

When pouring a boxful of castings on end it is generally better to let the metal rise from the bottom. Frequently, in arranging runners on a board, the metal runs down the ingate, and also runs into each mould as it goes downwards, and this is a usual arrangement. But when the castings are light, and there is risk of a chill occurring, it is better to reverse the position of the runners, so that the metal shall pass the upper ones and not enter them at all until the lower moulds become filled and the metal rises above them. This is done by sloping them upwards as they pass to their moulds, instead of downwards.

As a rather general rule, when any portion of a piece of work has to be machined, and is a working part, that is cast downwards. Thus the concavity of a brass is properly put downwards, and also the face of a valve. But cases often arise in which both top and bottom portions have to be tooled, and then sound metal in the top has to be ensured by light ramming and ample venting of the top part.

To produce large brass castings soundly, feeding by pouring fresh hot metal to replace that diminished by shrinkage is a frequent device. Feeding effected by pumping with a rod is much less frequent. It is sometimes practised, but the rods are more liable to get frozen up in the runner than they are in iron.

Gun metal should not be poured hotter than is necessary to fill the mould properly without chilling, and it should be poured as quickly as possible. The reason for this is, that being poured dull there is less time for the alloying elements to segregate. It leaves also less time for the moisture to decompose into its constituent gases—oxygen and hydrogen—and for the gas or gases that become occluded in the molten metal to become separated in the form of bubbles. It is more essential to fill a brass mould rapidly than an iron one. The metal is poured in sharply to fill the smallest areas before it has time to set in its passage. For the same reason it is necessary to pour some moulds with hotter

metal than others. There may be one or several pouring gates, and the strain on the mould is often relieved by risers.

As the shrinkage of brass is large—about $\frac{1}{8}$in. in from 9in. to 10in.—its exact amount being dependent on various conditions, brass in chunks is liable to draw considerably. When light and heavy parts are adjacent, the heavy parts will become concave somewhere or another, and will pull the lighter ones somewhat out of truth. This evil is to be guarded against by feeding. But ample venting and moderate ramming are also safeguards, in allowing the metal to fill the mould, unhampered by the presence of entangled air. Feeding is accomplished by pouring hot metal into the ingate or into the riser head, when such is added, to compensate for that which has shrunk down.

Although cracks do not occur in brass work to so great an extent as in iron, yet when weak and strong sections join, and there are no fillets in the angles, and hard dried sand or cores are in the way, feeding not being resorted to, these are conditions that are favourable to the formation of cracks.

The soundness of gun metal mixed directly from ingot tin and copper for heavy engineer's work can be relied on more than that of common brass mixed with scrap. Metal mixing is an occupation that calls for much experience and skill and exercise of common sense. Every different mixture used requires different treatment in the crucible, and also in the pouring. Some must be poured hot, others dull. Castings of different sizes required to be gated and poured differently. The waste of melting ingoted metal in a crucible ranges from about 3 to 6 per cent. The waste in melting turnings, chips, and miscellaneous scrap is variable, being as much as 25 per cent. or more.

Brass moulders deal with enormous quantities of similar work, and there are also great variations in the product. In engineers' brass fittings, hundreds, and perhaps thousands, of similar pieces will have to be cast in a foundry in a single year. Take the small cocks and valves, the plugs and glands, the nuts, handles, etc., or the parts of lubricators, safety valves, and hydraulic valves, and compare these with the cheaper class of goods. Some castings have to be capable of standing tests of 2000lb. and more to the square inch, others are comparatively soft and rotten; the first are of the best gun metal, the others the commonest brass. Both

the moulder and the metal mixer contribute to the ultimate result. In normal times the price of all common brass work is cut fine. Hence some of the fittings are so poor that they will twist off if screwed too tightly into their tapped holes. Others are tough, and close-grained, and sonorous. It is not easy to mix metal in all these grades from an unpromising pile of scrap of many classes. For the best work, therefore, specifications are strict that only certain proportions of copper and tin shall be used, that tests shall be taken, and the castings also subject to a definite hydraulic pressure. These tests are not applied to general work, for which quality can be fairly gauged by price. It is foolish to expect good gun metal castings at a price only two or three pence a pound more than the market price of tin and copper, or good gun metal fittings at a price equal to that of the cheaper class of work.

CHAPTER VIII

ELECTRIC FURNACES FOR BRASS MELTING

Electric Furnaces.—Although the electric furnaces for steel have been in use for several years, those for melting brass, yellow metal, and bronze are in the earlier stages of evolution. Even yet the question of the best design remains to a large degree a matter of individual opinion. It is proposed to take a brief survey of the subject as it stands at present.

The superior claims made for this method of melting over that effected in the furnaces that are heated with solid fuel or with gas, are these:

While the cost of electrical energy for melting is greater than that of fuel, the total cost associated with its use is less, because the expense of energy cannot be considered alone, since fuel is only one item in the total charge. There is attendance, waste, space occupied, furnace construction, and so on.

An aspect of the subject which tells in favour of electrical energy is that the use of the ordinary fuels involves combustion, and complete combustion is never attained in furnace practice, since the correct volume of air cannot be controlled. Electrical heating is not dependent on an air supply, but is itself a form of energy to be converted directly into heat. The difference from this aspect is great, since the largest proportion of the heat in a coke furnace goes away up the chimney, while in an electric furnace there is no chimney loss. Naturally, with the differences in the cost of electric power generated in different ways, and in various localities, the expense of melting varies correspondingly. But in any case it is claimed that it is cheaper than fuel heating.

In order to reduce expense it has been suggested that fuel heating may be used to preheat the metal, leaving the higher temperature to be developed by electric energy. There seems to

be no reason why the economy of preheating, which is included now in many furnaces, should not have this further application.

It is also stated that when hot metal falls into liquid metal and is melted, it takes up heat with greater rapidity than it would from hot gases. From this point of view preheating is economical, since it lessens the time of melting, and the metal is held in a liquid condition for a shorter period, and this in brass melting lessens the volatilisation of the zinc.

Another advantage of the electric furnace, which, however, it shares with some of the smaller fuel furnaces, is that the metal can be poured directly into the mould by tilting it. This saves the extra heat necessary to supply the loss in the ladle, and slightly lessens labour cost.

Further, in a closed electric furnace the metal can be melted in a non-oxidising atmosphere, which is a point of especial value when borings, turnings, and small scrap are being melted down. Since about 6% of the zinc in brass is lost by vaporisation in an ordinary two-to-one brass, this is worth saving.

Sulphur, which contaminates the metal in coke melting furnaces, is absent from the electric furnace. Hence, therefore, the metal is more fluid, and is less likely to produce castings with blowholes. Electric furnaces are of two general types—the arc and the resistance.

In the arc furnace the heat is generated in an electric arc which is formed in a short space over which the current passes between two electrodes, or between an electrode and slag or metal. The heat is transmitted to the metal below by conduction, and largely by radiation. The temperature of the arc must be that of the vaporisation point of carbon, or over 3000° C. In one design the arc is produced between an electrode of carbon and a thick mass of slag which covers the metal and heats it.

The objection to the arc furnace for melting brass is that the temperature is too high, being approximately 3000° C., or 5500° F., and it will volatilise the zinc. If the bath is covered by a coating of slag, that is hardly a remedy, because until the metal is melted it floats on the slag, and during that period there will be zinc losses. There will also be heat losses due to the heat having to penetrate downwards through the slag.

In one design of furnace the interiors of the furnace walls are heated with the arc, and the furnace is revolved to bring the metal over the heated walls. In another the metal is heated by radiation alone, the arc passing between two carbons located above the metal.

The resistance furnace operates similarly to the incandescent lamps, in which a filament that is too small to carry the electric current is overloaded, heats, and becomes incandescent. In the furnace the current passes through the liquid metal, or through the slag.

In the modern furnace the action is that of the alternating-current transformer. A transformer core is incorporated with the furnace, and the metal bath forms the secondary circuit. The primary coils of the transformer, which are in the cores of the transformer, are connected to the supply terminals. The current which produces the heat in the metal is thus induced in the charge, and not conveyed to it from the source of supply.

The furnace of the future may possibly be that resistance type in which the heat is generated in the metal itself. In this there need be no oxidation, since the atmosphere surrounding the metal can be made non-oxidising, or even slightly reducing, by the addition of charcoal.

The qualities which are necessary to ensure the success of the electric furnace for brass melting are, as in other furnaces, reliability, speed, and economy in fuel, labour, raw materials, and maintenance. Flexibility is essential, meaning by that the capacity to handle any of the brass and bronze alloys, turnings and borings, and dirty metal. If the electric furnace does not fulfil these essential conditions, it will not supersede the fuel furnaces in the brass foundry.

Except in regard to labour costs, the electric furnaces differ in the fulfilment of these conditions from fuel furnaces. Reliability depends much on simplicity of design, on the construction that will not get out of order with rough handling, or in consequence of the intense heat to which the refractory fittings and controls are subjected. The transference of heat from the refractories to the metal must be direct, without any obstacle being set up.

Experts hold that no one type of furnace is best suited for meeting all conditions of service. A furnace suitable for melting

red brass may be a failure for yellow brass or other alloys having a high zinc content. One capable of dealing successfully with very large melts may have a low efficiency when dealing with small ones. A furnace suitable for continuous service may not be economical when operated for a few hours at a spell. It may not be possible economically to change from one mixture to another, as in crucible furnaces.

The Rennerfelt Furnace.—The Rennerfelt, an arc furnace, is a Swedish invention. The electrode arrangement is unique, being

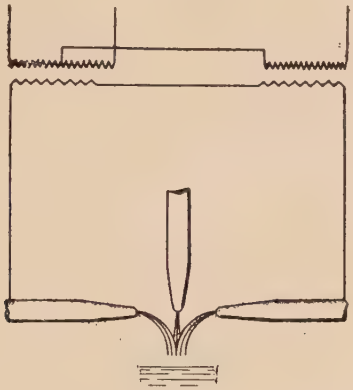


Fig. 248

special to this design. There are three electrodes, shown diagrammatically in Fig. 248, the purpose of the third being to force the flame produced between the tips of the horizontal electrodes down on the charge, and away from the roof. Polyphase, three-phase, current is used, transformed to a two-phase, three-wire system. The two side electrodes are connected to the terminal of each phase, and the top electrode to the middle conductor or neutral return of the system. The latter electrode carries about 40% more current than either of the side electrodes. These are about 15in. above the bath, or above the slag, in the larger furnaces, and the operating distance from tip to tip ranges from 18in. to 22in. The flame strikes the bath, so that the heat reaching the roof is indirect, which favours the prolongation of the life of the refractory materials of which it is composed. The electrodes are either of graphite or of amorphous carbon.

The Rennerfelt electric arc furnace as now made, Figs. 249 and 250, by Messrs. Hamilton and Hansell (Inc.), of New York, differs from the earlier design, in being round instead of square. The three-phase current used of any voltage and frequency is transformed to a two-phase, three-wire system, by means of two static transformers. The voltage between the neutral and one of the phases is about 100 volts, but it can, by means of taps on the transformer coils, be reduced, or increased, if necessary.

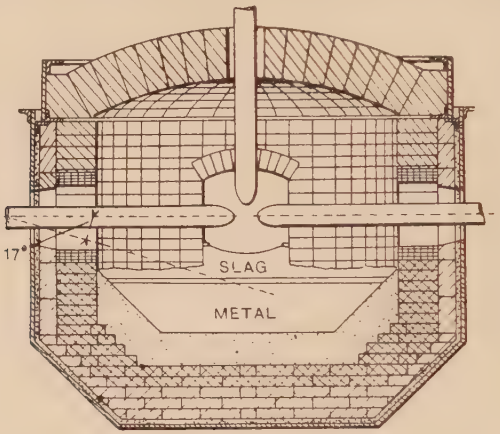


Fig. 249

The arc is formed between the tips of the three electrodes, and is thrown violently downwards by the two-phase current in conjunction with the electrode arrangement. The power input is regulated by changing the distance between the side and top electrodes, thus shortening or lengthening the arc. The adjustment can be made manually, or by electric motors, which can be controlled either automatically or by means of push-buttons. The top electrode is hand-operated, and must be between the two side electrodes, and should be moved down an inch or so at intervals, depending upon its consumption.

As the arc is free-burning, and therefore independent of any charge in the furnace, it is claimed that the violent current fluctuations which take place in furnaces where the charge constitutes part of the circuit, are avoided. There is no trouble in getting contact, as is sometimes the case in furnaces using bottom connections.

The power can be turned off and on as often as desired. The power factor is high, about 90%, with 60-cycle current.

Electrodes may be either of graphite or of amorphous carbon, and all furnaces can be supplied with water-cooled holders, and contact clamps suitable for both. The electrodes are provided with suitable joints, so as to ensure continuous operation. Several essential advantages offset the high cost of graphite electrodes: The electric conductivity of graphite is more than twice that of amorphous carbon, and consequently a graphite electrode of a given size will do the same work as a carbon electrode with double the cross-section. Cooling boxes and contact clamps, as well as the holes for admitting the electrodes into the furnace, can be made smaller to suit. An air-tight packing and a specially designed plate box are provided, which are necessary in order to exclude all air draught through the furnace, which would cause an excessive burning-off of electrodes. For the same reason the doors are made as air-tight as possible. The furnaces of a capacity of one ton or less have only one working door, which is used for both charging and pouring. Larger furnaces have one charging door and one pouring door. It is desirable with all electric furnaces to avoid the access of air to the interior of the furnace as completely as possible. After charging, the melting can proceed without any interruptions, by which the cooling-off of the furnace is avoided. As the arc is free-burning, the furnace can be preheated with electricity without using coke, oil, or other fuel.

The smaller furnaces are provided with two trunnions resting on roller bearings, and A frames, and are tilted either by hand or by motors, depending on the size. The larger furnaces are supported on heavy cast-steel rockers, Fig. 250, A, A, fastened to the bottom plate, to roll forward in tilting, by power applied through reduction gears. For special purposes, furnaces can also be equipped with an overlip tilting mechanism. In such a case the furnace is set in a cradle, is counterbalanced, and hoisted with the tilting fulcrum at the end of the spout, which, therefore, remains practically in the same position. This will permit of the pouring of small ingots or castings directly from the furnace without using intermediate ladles.

A special feature with the Rennerfelt furnace is that the side electrodes are made adjustable in a vertical plane—that is, to be

tipped downwards. With the side electrodes in a horizontal position, Fig. 249, there is ample space below for introducing the full charge without obstruction from the electrodes, even when

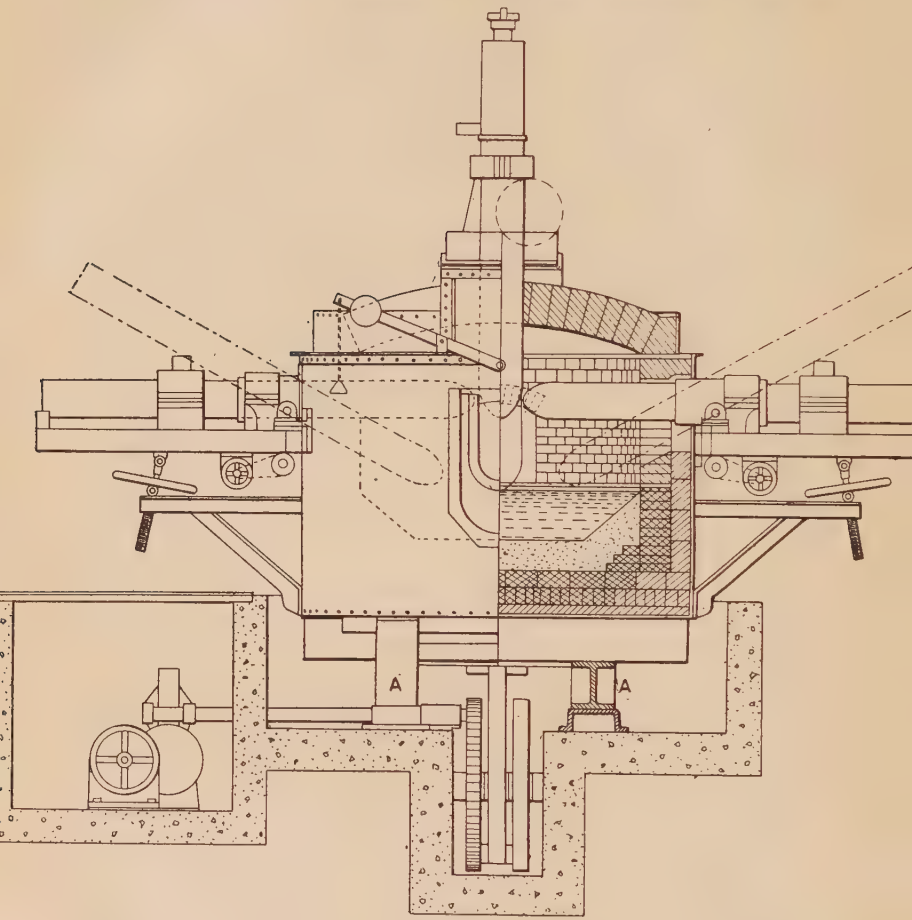


FIG. 250

using very bulky scrap. As the charge melts, the electrode tips are continually lowered, Fig. 250, keeping the flame about two or three inches above the metal or slag, and by the vertical adjustment the most suitable distance can always be kept between the charge and the arc. This is of great importance, due to the fact that the charge absorbs the heat faster, thus shortening

the time for melting down. For the same reason, the roof and walls are less exposed to the intense heat, and have a long life. By tilting the electrodes upwards, slagging-off, patching, and other work inside the furnace can easily be carried on.

The thermal efficiency of an electric furnace depends on many factors, such as heat insulation, but particularly on the rate which the heat, as generated by the electric current, is forced into the furnace. By increasing this rate the melting time is shortened, thus decreasing the power consumption and cost of melting per ton, and at the same time the output of a given size furnace is correspondingly increased.

The Rennerfelt furnace has a field amongst the non-ferrous metals; and various furnaces from 300lb. capacity and upwards are in operation, melting copper, red brass, cupro-nickel (composed of 75% Cu and 25% Ni), monel metal, bearing metal (composed of 82% Cu, 5% lead, 6% tin, and 7% zinc), bronze (95% copper, 4% zinc, and 1% tin), aluminium, etc.

Generally, all non-ferrous metals are melted in acid-lined furnaces on a ganister bottom, whereas the side walls and roof usually are lined with fire-bricks. For aluminium and aluminium alloys the bottom must be lined basic, with a fused-in lining of dead-burned magnesite. Furnaces producing bearing metal have a bottom constructed of carborundum sand mixed with fire-clay and molasses for a binder, but Chicago fire-brick is used for the side walls and roof. This lining remained in perfect condition after 300 heats, and appeared to be good for many heats more. In several instances 2000 heats have been taken off this same lining when melting copper, bronze, and similar alloys.

Results obtained in the Rennerfelt furnace are as follow:

CUPRO-NICKEL (75% Cu, 25% Ni) IN 1000lb. FURNACE.

Number of pounds to heat	1000
K.W.H. used per ton	500
Time per heat	90 mins.
Approximate loss	0·32%

BRONZE (95% Cu, 4% Zn, 1% Sn) IN 1000lb. FURNACE.

Number of pounds to heat	1000
K.W.H. used per ton	300
Time per heat	65 mins.
Approximate loss	0·32%

Bearing Metal in 2000lb. Furnace.

Total metal charged	8048lb.
Total metal recovered	7980lb.
Loss	68lb. (0·845%).
K.W.H. used per ton over an average of 116 heats	360 K.W.H.

(This includes pre-heating, testing, and melting time. Average time for making one complete 2000lb. heat from charge to pour, 90mins. In other words, 12mins. for charging, 70mins. for melting, and 8mins. for pouring. Electrode consumption, based on 104 tons of charge, using Acheson graphite electrodes, 5½lb. per ton.)

Aluminium in 1-ton Furnace.

K.W.H. per ton	210 (average).
Electrode consumpton	3 to 5lb.
Average melting loss	1·1%

Monel Metal in 1-ton Furnace.

Nickel	58%
K.W.H. per net ton, including preheating	700
Electrode consumption per net ton	10lb.
Average melting-loss	0·3%

Electrical Induction Furnaces.—The second group of furnaces operates by electrical induction. Several designs of these are in use. The principle underlying the design is this: When an electric current flows through a conductor, magnetic lines of force are formed round the conductor in concentric rings. If the current is discontinued the field dies down and cuts the conductor, inducing a voltage. If an electric circuit is so placed that the lines of force from the first conductor will cut it, then a voltage will be induced. With an alternating current the number of lines of force is constantly changing from zero to a maximum, and *vice versâ*, termed the frequency. The induced voltage is proportional to the number of cuts in unit time. If the lines of force are doubled, or the number of conductors is doubled, or the time halved, the voltage will be doubled. To increase the number of lines of force, iron is used to interlink the conductors. The combination of two coils and an iron core interlinking them comprises a transformer. The current is inversely proportional to the voltage, and inversely proportional to the number of turns.

The transformer of an induction furnace supplies any voltage required, either higher or lower than the supply voltage. The primary coil is connected to the supply, the secondary coil with the changed voltage. The voltage is proportional to the number of

turns. An induction furnace is a short-circuited transformer under control. The secondary is formed by the molten metal.

The principle requires modification to make it workable. Two undesirable aspects call for notice—what is termed a low-power factor, and the phenomenon termed pinch effect. With reference to the power factor, it is essential to the proper design of the transformer to have the primary and the secondary coils as close together as possible, for if not, many of the lines of force will not interlink the two coils, and a low power factor will result. In the induction furnace, where the secondary is formed by the molten metal, this cannot be placed very close to the primary coil because a thickness of refractory material must be interposed for the insulation of the heat, and the secondary must have some necessary length to offer the resistance required.

In induction furnaces of the open horizontal-plane type—that is, those in which the molten secondary lies in a horizontal plane, the open channel design—the power factor is low, and it becomes proportionately lower as the size of the furnace is increased, and as current of increased frequency is used. Also in these the metal is low when the furnace is started and the resistance is high. As further amounts of metal are added, and the quantity and cross-section are increased, the resistance is lessened. It is not possible to increase the current density beyond a certain maximum because a break occurs in the current path due to the pinch effect, a fact which was first observed by Dr. Carl Hering.

The circulation of metal through pinch effect is caused by the contraction of a molten conductor through which a high current is sent. If the current is sufficiently increased the circuit will be interrupted at the point of smallest cross-section, and will prevent a further increase of current, which is fatal to the operation of the furnace. This is not the case in steel. Because of its high resistance, the current required to melt it is not sufficient to cause the pinch effect. But in the brass alloys of low resistance the pinch effect interferes with the proper running of the furnace. This condition occurs only in induction furnaces that have the molten secondary in a horizontal plane of the open-channel type.

The Schneider Furnace.—The pinch effect was counteracted in a patent furnace, shown diagrammatically by Fig. 251, by M. Schneider, of Creusot. In this the molten metal was included in a

closed channel or channels constituting a secondary loop, upon which hydraulic pressure was exercised from a pool of metal with a head. The head sufficed to prevent rupture of the circuit if pinch force of such magnitude were present sufficient to break the circuit in an open-channel furnace. The patents broadly claim—"in combination, a chamber for holding molten metal, one or more pipes communicating with said chamber, so constructed as to permit circulation of molten metal, an iron core encircling said pipe or pipes, and means for producing lines of force in said core." The closed-channel induction furnace, as originally designed by Schneider, in which a hydraulic head is maintained by means of molten metal in a pool above the channels, is the only form using alternating current which is practicable for melting non-ferrous mixtures.

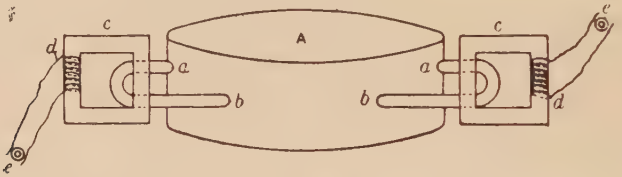


Fig. 251

Fig. 251 shows the Schneider furnace diagrammatically. A is a circular melting pot in communication with two U-shaped heating tubes (*a*, *b*). Through each loop formed by the tubes a magnetic frame or iron core *c* passes, carrying the primary winding *d*, traversed by alternating current from the dynamo *e*, whereby magnetic lines of force are produced in the iron core *c*. Two melting pots may be connected by the circulation and heating tubes. A U-shaped tube then heats one of the melting pots. The induced currents are produced by magnetic frames on cores provided with windings.

The Ajax-Wyatt Furnace.—The Ajax-Wyatt furnace, built by the Ajax Metal Co., of Philadelphia, is an induction type. One form is shown by Figs. 252 and 253, and by the photograph Fig. 254. It has, Figs. 252 and 253, a body A and channel B, connected by a transformer C. These, with the casings for the body, are rotated about trunnions *a*, *a* in any suitable bearings by means of the worm-wheel seen in the figures. In this particular

form the furnace body, adapted to receive a pool of molten metal, and melt the pieces of metal down into it, is made up of an outer jacket A, lined at D, and carrying a pouring spout *b*. The upper portion of the body is partly closed by an annular tile E, held in a shell F, and having a conical opening, in the annulus of which fits a plug carried by a cover G and hinged at *c*. The shell F is secured to the jacket A by means of ears, and bolts H. In this construction it is preferred not to connect the

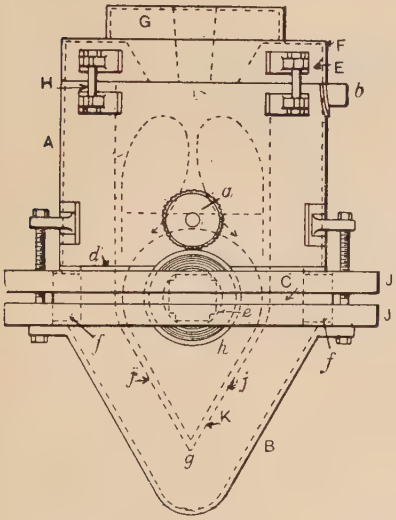


FIG. 252

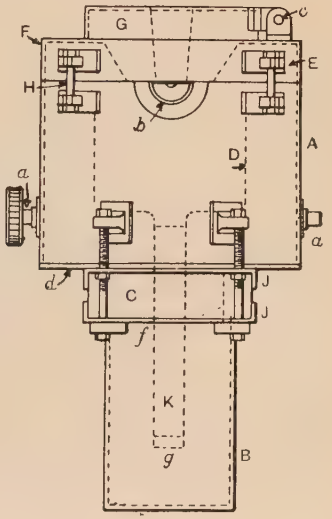


FIG 253

casing, within which the lower part of the channel B is formed directly with the body of the furnace, but to interpose the transformer between, and so form part of the channel actually within the transformer, in preference to having the channel member merely pass through a gap in the transformer. In this way the shell type of the transformer is built into the unit, and forms part of the mechanical protection and frame of the complete furnace, reducing the metal parts and avoiding interruption of the magnetic circuit of the transformer, in order that it may be put in place, and reduce heat losses. The transformer C is conveniently connected to the other parts by the use of angle irons J, J at the top and bottom. Bolts pass through these, and through ears on the jacket and flanges of the casing, clamping the body, trans-

former, and casing firmly together. The bolts are secured by nuts, and corresponding nuts separately engage the undersides of the upper angle irons. A pair of brass spacing plates is shown at *d*.

The transformer shown is of the single-phase shell type. Its laminated magnetic circuit has a central leg *e*, and end legs *f*, *f*. To accommodate a close circular winding, the edges of the central leg are cut, as shown, and the winding is put on in the form

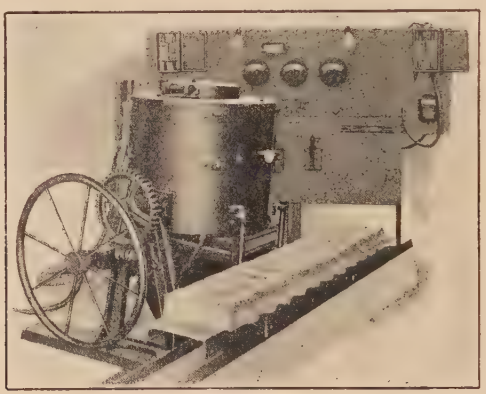


Fig. 254

of a series of layers of parallel circular bands, forming a circular primary winding. In the structure used, the primary winding, indicated encircling *e*, is formed from a flat strip of conductor wrapped with asbestos insulating tape, and applied in rings interrupted at the points of cross-connection with adjoining rings, and also cross-connected from one layer to the next at the ends of the rings adjoining layers.

The casing B is a casting designed to engage the angle irons on opposite edges of the lower part of the transformer, and to engage the edge of the primary winding. In lining the furnace frame thus formed, a two-part pattern is inserted having the shape of the channel and pool, and having a division line between the parts at some point, as *h*, so that the lower part of the cement lining used could be placed and rammed before the upper part of the pattern can be inserted, and the lower part of the pattern is put in place. Plastic material is then rammed about the form

inside and out, completing the lining within the casing, transformer, and body of the furnace, and filling the entire space about the primary winding, except the portion occupied by the pattern. The pattern is then burned out. A clay and asbestos insulating compound is used for linings. This is subsequently dried out gradually.

The channel K is flattened in cross-section, preferably of rectangular or approximately rectangular shape, and with the longer dimension of rectangle parallel with the axis of the transformer winding. The channel length is formed with an acute angle at the turn at *g*, outside of the furnace, and in the turn at the pool acute angles are avoided, the contour being rounded between the connections with the pool, or at least obtusely angled where the connections are made with the furnace.

When electric currents traverse fluid conductors (such as molten fluid in the channel parts *j*, *j*) and flow in opposite directions, electro-dynamic forces are set up in the conductors in directions perpendicular to the lengths of the conductors, tending to separate the conductors. These forces vary directly in the product of the current flowing in the two conductors (as the square of the current where the same current flows in each), and inversely as the distance between the parts of the fluid affected. Where these conductors are not parallel, the electro-dynamic forces vary in magnitude from one point to another along the lengths of the conductors, because of the differing distances separating them at these points, which cause correspondingly varied hydro-dynamic forces tending to produce motion of the fluid parallel to the lengths of the conductors. The application of motor effect causes motion of the fluid, and hence circulation if the fluid is free to flow. The motor effect causing this circulation may be intensified by bringing the conductors together into an angle, and becomes most effective where the angle is acute, increasing within reasonable limits with the acuteness of the angle. Though Joule effect and some pinch effect are also present, the hydro-dynamic pressure due to electro-dynamic motor effect is the dominant force in the Ajax-Wyatt furnace, which not only depends generally upon this pressure for circulation of the heated metal, but derives great advantage from the intensity of the pressure in the angle, where overheating would otherwise occur.

The Ajax-Wyatt furnace is similar to the Schneider in that it uses a closed channel, with a pool above the channel and circulation of the liquid metal in the channel. Without circulation, a furnace of this type would be entirely impracticable for the reason that it is in the channel that the heat is generated, owing to its restricted cross-section and relatively higher resistance.

In this furnace it is possible to melt 60/40 brass without volatilisation of zinc in the channels of the secondary circuit, so long as the cold metal is being fed into the furnace, or the bath in its entirety has not reached the temperature at which the zinc is volatilised. It is interesting to know that as soon as the bath has reached the correct pouring temperature, the needles on the instruments begin kicking. The test now used by the melter in the brass rolling mills to determine the casting temperature is to immerse an iron bar in the molten metal. If the melter feels a kick upon the bar he pronounces the temperature satisfactory. This kick which is felt is simply due to the so-called boiling of the metal—that is, volatilisation of zinc.

The furnace may be fed with turnings, ingots, etc. The charge may be added rapidly, as there is no danger of solidifying the metal in the secondary channels, or in the lower portion of the pool above them, the only precaution necessary being to exercise care to prevent bridging of the charge. The furnace is entirely noiseless in its operation, very cool on the outside of the jacket, and uses no water in cooling, therefore is absolutely safe from any danger of having the heated metal come in contact with water, and the consequent results. The shape of the hearth closely approximates that of an ordinary crucible—in fact, very closely approaches the ideal for minimum of heat losses, which is a spherical form. It is possible to seal the furnace tightly to prevent oxidation. The heat is generated in the charge itself and at the bottom of the charge. All the forces effective in the channels have the tendency to carry the heated metal upwards and so bring it in contact with the metal to be melted. Consequently there is constant and energetic automatic circulation. The conditions in all these respects are ideal for high efficiency and minimum of metal losses.

The power factor of the 30kw. furnace is 85%, and of the 60kw. 72%. The load is a perfectly steady one, so that from the

power-house standpoint such a furnace load is as desirable a load as could be imagined. On furnaces which are operated on 24-hour day schedule the load factor approaches nearly 100%. The Ajax-Wyatt has melted several million pounds of yellow metal, a large proportion of which has been in the form of turnings. The composition has varied from 70/30 to 60/40, with lead as high as 3%, so that the figures hereafter given are not based upon isolated test runs, but cover commercial practice.

The furnace at present is made in two sizes, with normal rating of 30kw. and 60kw. They are made to operate on single-phase circuit, 220 volts, 60 cycle. It is, of course, possible to accommodate the construction of the furnace for other current conditions, and for polyphase current, and still larger capacities. Such development remains for the future.

To start the furnace, liquid metal is charged into it in just sufficient quantity to fill the secondary loop, and maintain a satisfactory hydraulic head. The starting charge for the 30kw. furnace is 75lb., and for the 60kw. 125lb. The 30kw. furnace is capable of pouring at one charge 300lb. of metal, thus making the full contents of the furnace, including that required to maintain a secondary loop, 375lb. The 60kw. starting charge being 125lb., and the quantity of each cast being 600lb., make the total capacity 725lb. The melting rate of the 30kw. furnace has been from 6½lb. to 9lb. per kilowatt, and of the 60kw. from 7½ to 11lb. per kilowatt, the lower figure being based on melting 70/30 brass in the form of very bulky turnings which were difficult to charge, and the latter figure on extrusion metal, approximately 60/40, the usual rolling-mill mixture, part scrap and part new metal, these figures being based on the weight of the metal cast. The temperature of the cast metal averages 1950° to 2000° F.

The Baily Furnace.—The Baily electric furnaces, by the Electric Furnace Company, of Alliance, Ohio, U.S.A., are of the resistance type, Fig. 255. The heating element is the annular trough seen encircling the upper part of the furnace, and filled with granulated carbon. The trough is made of carborundum sand, a highly refractory substance which expands and contracts. Contact is made with the contained broken carbon by electrodes which are located opposite each other, their ends entering the circular trough. The temperature of the furnace and its melting

capacity are controlled by voltage taps that are brought out from the secondary of a special transformer that is supplied with the furnace. The electrical equipment includes an oil-break, a switch, a low-voltage transformer, and indicating meters. If desired, a contact-making pyrometer is supplied, by means of which the oil-switch may be automatically tripped open when the furnace has reached a pre-determined temperature.

The furnace shown by Fig. 255 is of a standard 150kw. size, rated at a hearth capacity of 1500lb., with a melting rate of

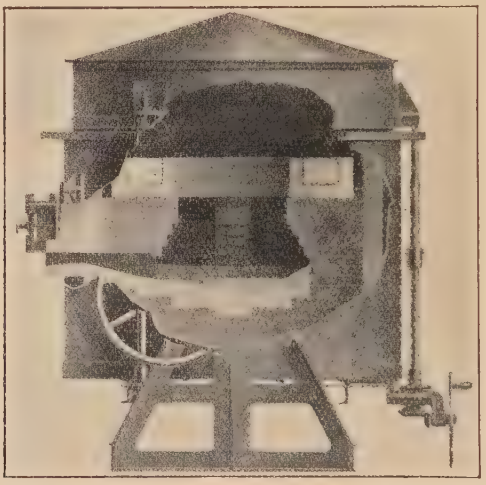


Fig. 255

600lb. per hour. These furnaces, therefore, are not adapted to the work of the small foundries, but only for shops having a large output. Charges of less than 400lb. cannot be handled economically. Furnaces are made tilting, like that illustrated, or non-tilting. The shell is 7ft. diameter, lined with firebrick, supported on trunnions, with geared provision for tilting and with a double-hinged door.

The Hering, an electrical resistance furnace, is a type by itself. The principle is that of heating the liquid metal from the bottom, associated with a tilting mechanism for pouring. Small portions of liquid metal are heated with great rapidity in cylindrical holes in the bottom of the hearth. They are then ejected with considerable force into the main body of the molten metal, fresh metal

being continuously sucked into these holes. All the heat in the furnace is generated directly in the metal itself, and it therefore is in instant contact with the metal, which is preferable to the slower processes of conduction, and of radiation. This has been termed, therefore, the "pinch-effect" furnace.

Fig. 256 shows diagrammatically the circulation of metal through pinch-effect. The phenomena was first observed in a resistance steel furnace with open channels, and it was fatal to the action of the furnace by the pinching off of the column of liquid. This is due to the fact that when the current reaches a

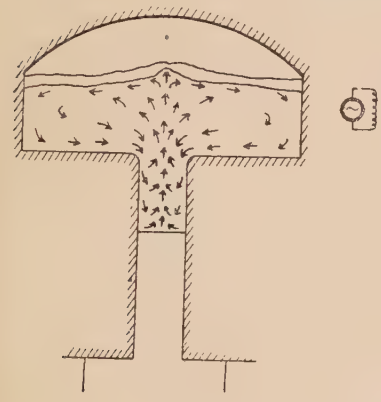


Fig. 256

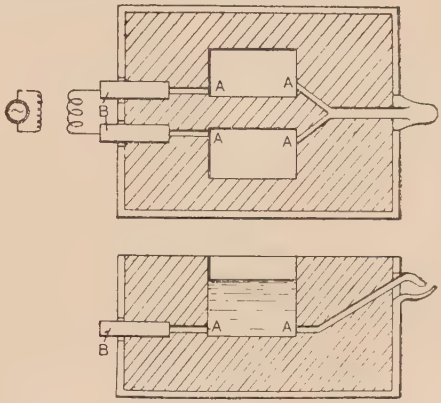


Fig. 257

certain limit, which depends on the cross-section of the column, and its shape, and the specific gravity of the liquid, it becomes contracted by electro-magnetic forces until the circuit is broken. If, as Dr. Hering devised, a liquid conductor is confined in a vertical cylindrical hole in the bottom of the hearth, Fig. 256, opening into the main body of the metal, and closed at the bottom by means of the electrode, and then if a current is passed lengthwise through it the effect of the pinch will be to contract the column towards its central axis. The effect, therefore, will be that metal will circulate from the circumference towards the centre, as indicated by the arrows in the figure. An axial movement will follow, which will drive the liquid out of the column.

The Hering Furnace.—Diagrams of Hering designs are given in Fig. 257, a bottom pouring furnace, and in Fig. 258 the tilting

design. The general scheme is as follows: A plated shell is lined to form a hearth. In the hearth are several cylindrical holes

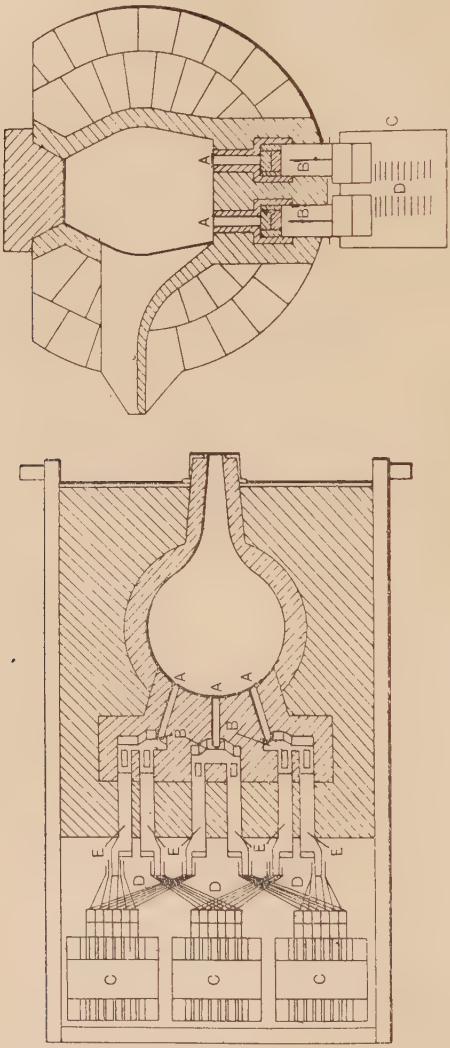


FIG. 258

extending into the lining and terminating at their outer ends in metallic electrodes. These are usually made either of the same metal that is to be melted, or of graphite. The electric current,

led into the furnace by the electrodes, passes through the columns of liquid metal in the holes. Here the electric energy is converted into heat, and the freshly heated metal is driven out into that on the hearth. It is estimated that each particle of metal in a hole is only retained on an average during a period of one second, but that it is heated by about 50° C. higher than when it entered. These heating holes A in the figures are termed resisters, because the electric resistance of the metal occupying the holes causes the conversion of the electric energy into heat.

The electrodes B come to the outside of the furnace, where they are attached to transformers C, in which the kind of current used is adapted. Any of the usual alternating currents can be adapted, single-, two-, or three-phase, the latter generally having preference. The safe voltage for lighting and power circuits is to be preferred to high voltages. The currents should be large, with low voltages and great amperage. To start the furnace from the cold condition, it must be primed with a small charge of liquid metal sufficient to fill the resister holes and the bottom of the hearth, in order to establish the circuit for the current. A few fragments of tin, zinc, or aluminium inserted, ensure the union of the priming metal with the electrodes. When the furnace is shut down, it is tilted until the heating holes are emptied, except for a short stump at the bottom. In Fig. 258, D, D are secondaries, and E are water blocks.

These furnaces work at their best efficiency when they run continuously, which is also better for the lining, which is liable to become strained by repeated heating and cooling. If run intermittently the furnace may be kept hot over-night with little current, about 20% or less of its normal input.

The Detroit Rocking Furnace.—The Detroit rocking electric brass-melting furnace, Fig. 259, built by the Detroit Electric Furnace Company, Michigan, U.S.A., is of the indirect arc type. The rocking motion is imparted in order to effect a thorough mixing of the metal and its superheating, and thus prevent that excessive local heating which is liable in a non-rocking furnace of arc design to result in a loss of zinc. This furnace was developed by Mr. H. W. Gillett, of the U.S. Bureau of Mines. It is now used extensively for melting yellow brass, red brass, and bronzes of various compositions.

One of the principal items in the cost of melting copper alloys, particularly in those which contain large percentages of zinc and lead, is the loss of these metals by their volatilisation and oxidation. Though this cannot be entirely eliminated, it is reduced to a minimum in a tightly closed furnace, with a neutral or a reducing atmosphere, free from the draught of furnaces fired with solid fuel. Here the electric furnace scores, because the

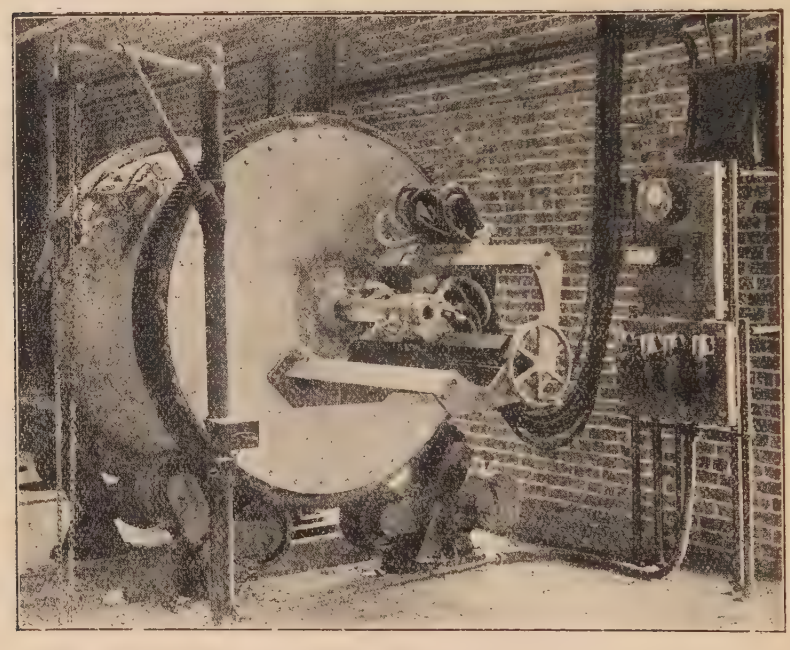


Fig. 259

vapours accumulate in the chamber and set up a pressure that prevents further vaporisation. To secure this result it is necessary that all portions of the bath of metal should be heated to a fair degree of uniformity. Too intense or too rapid an application of heat to a limited portion of the bath would result in raising that portion to an excessive superheat before the colder metal had reached the desired pouring temperature. This would result in a rapid loss of volatile metals. In the ordinary indirect arc type of furnace, where the heat is applied above the melt, since hot metal is lighter than cold, there is little circulation in

the bath. If the rate of heat input is rapid, the conduction of heat from the top of the melt downwards is less rapid than that of the heat supply, and the surface becomes superheated. Then the boiling point of zinc will be reached before the lower portions of the metal are hardly melted. The zinc vapour will create a pressure that will result in its leakage.

The remedy for this imperfect melting is to stir the metal vigorously, so that a uniform temperature is maintained and surface super-heating prevented. This is the claim made on behalf of the rocking furnace Fig. 259. It is so called because the furnace is oscillated through about 80°, during which the solid portions of the metal are washed about in the molten part of the charge and tumbled over, so that fresh surfaces continually receive direct radiation from the arc. The furnace shown has a drum 5ft. in diameter by 5ft. long. It has brick linings 12in. thick, a hearth 3ft. by 3ft., taking charges of 1300lb. and upwards. The graphite electrodes are 4in. in diameter; they are threaded for continuous feeding, and are adjusted by screw-operated supports of the lathe slide type. Single-phase, 60-cycle current, stepped down to 120 or 130 volts, is used. The current varies between 1000 and 2000 amperes, 1650 being about the average. The slack given to the flexible leads is necessary to allow of the rocking of the furnace. The furnace is mounted on rollers, and the ring gears permit it to be rocked up to a maximum of 200°. The motion is actuated by a small induction motor through a reducing gear immersed in oil and enclosed in a tight gearcase. The action of the motor is controlled by an automatic reversing switch which can be set to give the desired angle of rock.

The source of heat is an electric arc, between horizontal graphite electrodes, placed axially in the furnace, and meeting at the centre of the cylindrical melting chamber. These are controlled by hand-wheels, which permit them to be entirely withdrawn from the furnace chamber if desired. One of the electrodes is set in such a way as to locate the arc approximately at the centre of the furnace, and is afterwards allowed to remain stationary, while the operator controls the arc by the adjustment of the other electrode.

The method of operating is as follows: During charging, the electrodes are withdrawn until their tips are flush with the inner walls of the furnace, in order to avoid striking them with the charging of heavy pieces of metal. The furnace is then closed, the electrodes adjusted to their correct positions, and the arc is started. During the first few minutes of the melting period the furnace is not rocked, since rocking at this stage might cause fracture of the electrodes. As the metal becomes fused the rocking is commenced, through a small angle at first, and reaching its maximum as the metal becomes completely molten and enters on the superheating stage. During the complete rock the molten metal washes the inner lining of the furnace to within a few inches of the charging door at each end of the oscillation, at the rate of, approximately, two complete oscillations per minute. The charge when molten lies in the lower half of the furnace at a distance of from 7in. to 10in. from the arc. The metal is thus heated by direct radiation from the arc, but the stirring action that results from the rocking of the furnace is sufficient to maintain a constant temperature throughout, and so prevent the surface-overheating that would result if the furnace were stationary. When the pouring temperature is reached, the arc is broken and the metal is poured through the spout beneath the charging door. If from any cause the metal cannot be poured immediately, it can be held in the furnace without danger of over-heating, since no part of the furnace is appreciably hotter than the metal. And if thought desirable, rocking can be continued to ensure a uniform temperature and a thorough mixture.

The arc is not more than 10in. from the metal on a full charge, and it is approximately 18in. distant from the nearest refractories—the vertical end walls—and 20in. from the cylindrical walls. Thus a rapid rate of heating is possible without injury to the linings, while overheating of the surface layer of the metal nearest the arc is prevented by the constant mixing. Using charges of 2000lb., the furnace will produce approximately 2000lb. of molten brass per hour melting time, or about 1500lb. per hour reckoning the time consumed in charging, in pouring, and incidental delays.

The thermal efficiency of the rocking furnace is high. This is primarily due to the fact that approximately four-fifths of the

surface of the refractory lining is washed by molten metal consequent on the rocking action. Most of that portion of the lining which is exposed to direct radiation of heat from the arc, and which thereby becomes hotter than the metal, is intermittently brought into contact with the metal, and renders up its excess heat to it instead of wasting it through the outer walls. Since the linings are thus subjected to a constantly recurring cooling action, they are maintained at a relatively low temperature, with the result that radiation losses are lower than they could be in a stationary furnace.

In this furnace it is stated that clean yellow brass can be melted with a loss of below 1%, and with red mixtures the net loss is not usually above 0·5%. Very dirty borings, and fine scrap of all kinds, though more wasteful, are often melted with losses not exceeding 2%.

Careful tests made on a series of heats have proved that a perfect mixture of the metals which go to make an alloy can be readily obtained by reason of the brisk agitation which the molten metal receives. Even high-lead alloys can be poured from the furnace in homogeneous mixtures. This also renders it possible to duplicate a complex alloy in heat after heat, with a minimum deviation from the composition specified. Thus, in a routine analysis from thirteen consecutive heats, from a rocking furnace melting phosphor bronze, the maximum deviations from the average were: Copper, 0·75%; tin, 0·60%; lead, 0·36%; zinc, 0·54%; phosphorus, 0·008%. The average deviation from the average was: Copper, 0·22%; tin, 0·06%; lead, 0·10%; zinc, 0·23; phosphorus, 0·004%.

The number of kilowatt-hours required per ton of metal varies widely, depending upon the nature of the alloy melted and upon operating conditions. One rolling-mill on brass has averaged 221 kilowatt-hours over a total of several hundred heats. An average of eight- to ten-hour operations on clean scrap and new metal mixtures shows about 250 kilowatt-hours for yellow alloys and 275 for red alloys. If a high proportion—say, over 50%—of very oily or wet borings and grindings is included in the charge, the energy consumption on 2000lb. charges may be as high as 300 kilowatt-hours per ton.

The usual life of the refractory furnace lining is prolonged by the continual washing to which most of the surface is subjected. This cools the lining to a temperature but slightly above that of the metal itself, which is well below that critical temperature which would erode the brick. A single lining lasts for about 350 heats in average practice, after which it has to be repaired. The intermediate and outer linings ordinarily require no replacement.

There is a consideration of an altruistic character which applies generally to electric furnaces. The fumes of zinc oxide, which are so disagreeable a feature in all brass-foundries using open fires, are eliminated almost completely by the closed electric furnaces.

The Booth Furnace.—The Booth electric brass-melting furnace is a completely rotating design, making two revolutions per minute. A feature of this design is that the pouring spout is placed in one end, closed by a hinged door, instead of in the side of the cylinder, where an opening breaks the continuity of the lining. Putting the pouring opening in one end permits of the continuous rotation of the furnace. The shell is rotated on rollers, without gears, driven by a motor. The electrodes are brought in at each end of the shell, and their spacing is regulated by hand in the smaller furnaces, or by automatic control in the larger. The cylindrical lining is made of two cylindrical tiles, which fit together with a tongue and groove joint at the centre, the joint being filled with heat-resisting cement. The ends of the furnace are lined with four special bricks, joined with cement, and cemented to the cylindrical tiles. The furnace is therefore a large crucible. The door is a solid piece of brick, through which the electrode passes. The large furnaces are provided with two doors. The linings are backed with a layer of heat-insulating material, so that the temperature of the shell is so low that the hand can be placed on it. The furnaces are made in capacities ranging from 250lb. rated holding capacity, to 3000lb., so catering for the requirements of the smaller as well as the larger foundries.

When ingots or heavy scrap are to be melted, the furnace remains stationary until the charge is partly melted, and then rotation is started and continued until the metal is ready to be poured. If turnings and borings are used, the rotation commences

on charging, and the electrodes receive no damage. When about to pour, the operator stops the rotation when the tapping hole is above the surface of the metal. The hole is then opened with a sharp-pointed steel rod, which picks out the sand used for closing the hole. The furnace is then rotated down until the opening is below the surface of the metal, which is then poured. If a portion only is required, the furnace is rotated back to bring the tap-hole above the surface.

In melting turnings, borings, and grindings with a hot furnace, thirty to forty minutes is required per charge. With a small

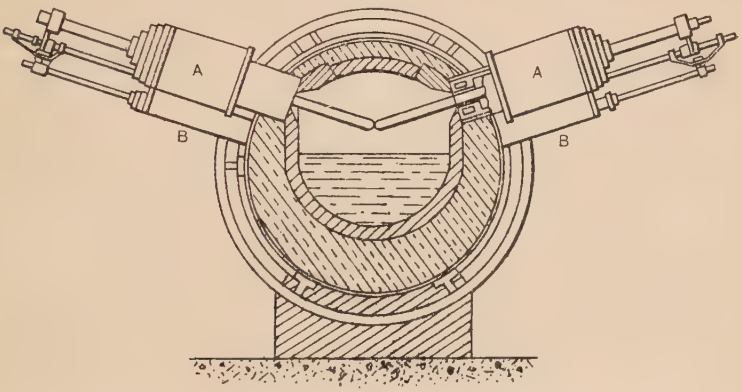


FIG. 260

furnace the average power consumption would be from 250 to 300 kilowatt-hours per ton. With yellow brass turnings and borings, if fairly clean, the loss is about 1·5%. In melting ingots and heavy brass scrap a heat will average from half an hour to an hour in length. With a 250lb. furnace a ton of metal can be easily charged, melted, and poured in from $7\frac{1}{2}$ to 8 hours.

The Stassano Furnace.—Fig. 260 is an adaptation of the Stassano furnace, originally designed for dealing with copper ores, to the melting of copper and its alloys at lower temperatures. It works on the arc principle, the length of the arc and the intensity of the melting being under the control of hydraulic cylinders. From the cross-sectional view it will be seen that the two electrodes enter the furnace from the sides at an angle, being directed downwards towards the bath, and that they occupy a

position approximately midway between this and the roof. Water-cooled jackets A protect the electrode holders. They contain an inner tube electrically insulated from the other parts of the holder, which tube is connected with a water-cooling system. The movements of the electrodes are regulated by small hydraulic cylinders B located underneath the water jackets. These are double-acting, and are governed by four-way cocks mounted on a standard near the furnace. If water under pressure is admitted behind the piston of the hydraulic cylinder, it will move outwards, and draw the electrode holder with which it is connected in the same direction, so increasing the space between the points of the electrodes. This will cause a diminution of heat in the furnace. A movement of the piston in the reverse direction increases the temperature.

The melting chamber is of elliptical section taken transversely, and rectangular in the longitudinal direction. The charging door is at one end. The furnace chamber is lined with magnesite, surrounded with firebrick, enclosed in a steel shell. The melting chamber is located eccentrically in the shell. Either direct or alternating current can be used, and single or three phase, and a voltage of from 75 to 220 volts according to the size of the furnace. The complete closing of the melting chamber from access of air is an advantage in this as in other electric furnaces. The temperature regulation is simple, and a high power factor is claimed.

Crucibles.—A large number of experimental furnaces of the resistance type have been constructed, in which the metal is heated by the passing of currents through the walls of a crucible. These do not appear to have proved commercially successful in face of the difficulties attendant on their working. Yet they afford some promise for the future. The current is passed through a granular resistor of crushed coke, or granular carbon or graphite, in which the crucible is embedded. Solid plates of carbon have been tried. In each design constructional variations occur, and certain objectionable features seem inevitable. One of the most serious relates to the lifting out of crucibles, with disturbance of the resistors. To avoid this the crucible may be left in place and the furnace tilted for pouring. Another concerns unequal heating of the resistor and possible burning out of holes in crucibles.

Morgan Crucibles.—The Morgan Crucible Company Limited in England have experimented in this field. One of the difficulties encountered is that of shaping the cross-section of the crucible so that the heat generated produces uniform temperature over the heated area, and also the use of a heavy current of low voltage consequent on the low specific resistance of the material, and the thickness of the walls that is necessary to withstand the stresses to which the crucibles are subject. Another concerns the proper mounting of the crucible to secure freedom for its expansion and contraction and its adequate support, since it becomes soft when heated. As on the one hand a large proportion of plumbago is desirable to enable the crucible to withstand frequent changes of temperature, while on the other hand it has a low specific resistance, difficulties in proportioning and in manufacture arise to avoid risks of unequal shrinkages and local overheating. Another difficulty relates to the terminals, which have to carry heavy current, and are mounted at opposite ends of the crucible.

A tilting electrically heated crucible has been designed by this company, having the general outline of the ordinary crucible with a pouring spout, and mounted on trunnions fitted with worm-gear. The crucible is extended at the top into a charging hopper, and is closed with a refractory cover. The casing is lined with heat-insulating material and a refractory lining, a small space between the latter and the crucible being occupied with refractory material. The interior of the crucible is provided with a thin refractory lining, which prevents the metal from making electrical contact with the crucible, and so diverting the current. Heavy gun-metal water-cooled terminals are clamped on the thickened ends of the crucible. The crucible holds 150lb. of brass, and requires a current of about 1000 amperes, at 20 to 40 volts. Either direct or alternating current can be employed.

A much larger pattern of crucible, to take 800lb. of brass, is made in the form of a horizontal trough, with a spout at the centre. It is mounted in a larger trough of cast iron, from which it is isolated by refractory linings in the manner just described. The trough shape lends itself to ease in mixing, and stirring the charge, particularly of large ingots and long pieces of scrap. The spout pours from the bottom of the trough.

New Type of Rennerfelt Furnace.—A new design of the Rennerfelt furnace has been introduced by Messrs. Hamilton and

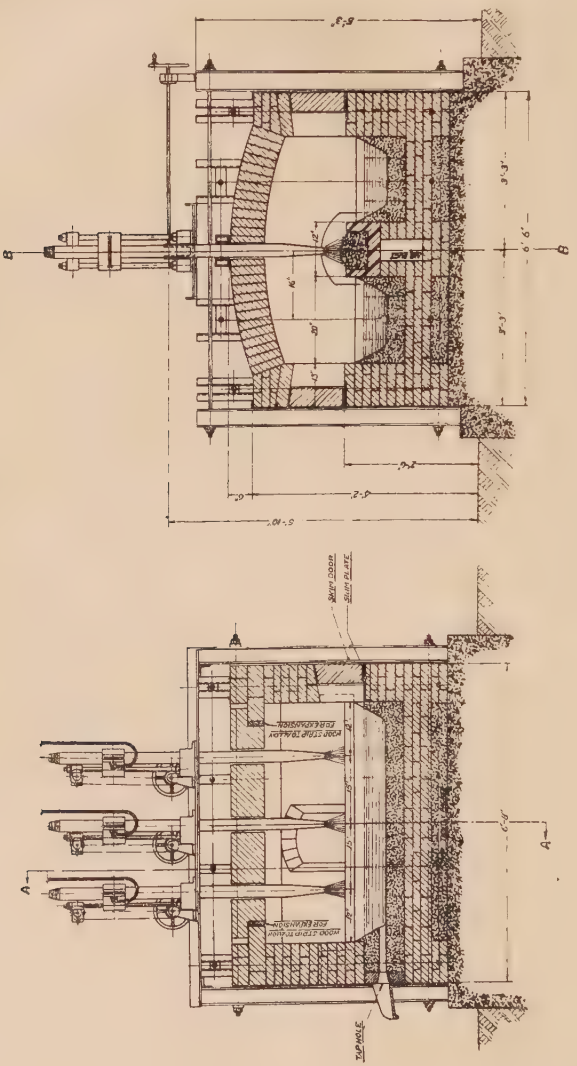


FIG. 261.

Hansell Inc., which is of the reverberatory type, see Fig. 261. It is a three-phase furnace, designed for the melting of non-ferrous metals, containing zinc and similar metals. As will be

seen from the sections, it has two hearths and a trough of carborundum located between them. The three electrodes are inserted perpendicularly through the roof, and are connected to the phases of three-phase current of 100-volt potential. But taps provided on the transformers will give lower voltage and reduced transformer capacity in proportion.

Arcs can be drawn between the electrode tips and a crushed carbon filling in the trough, or the electrodes can be fed in direct contact with the carbon filling, so that a smothered arc can be obtained, or the heat can be generated by radiation from the incandescent mass. In such ways it is possible to obtain a wide range of temperature, but a smothered arc, on account of the indirect heating by means of radiation, will give a lower temperature, thus avoiding excessive volatilisation of metals like lead, tin, and zinc.

The furnace can be made of either the stationary or the tilting type. The first will have each hearth tapped separately through tap-holes, but in the second the two hearths will be tapped from a combined spout.

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